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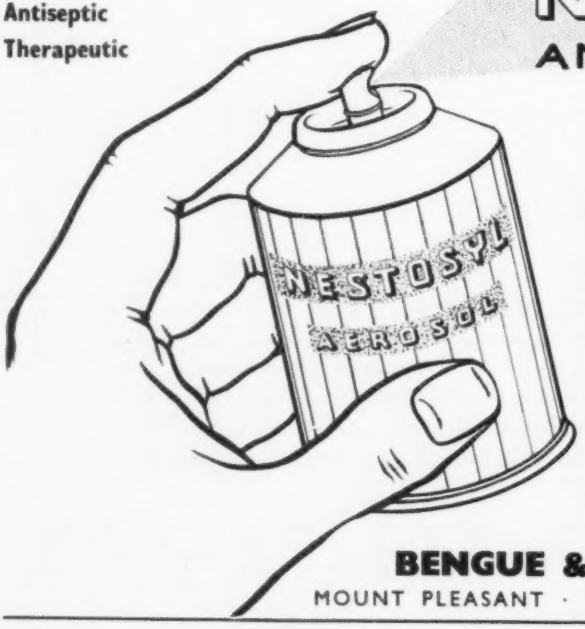

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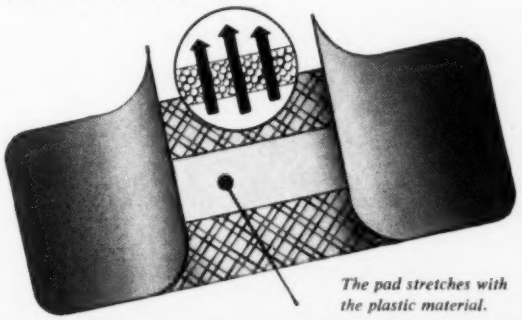

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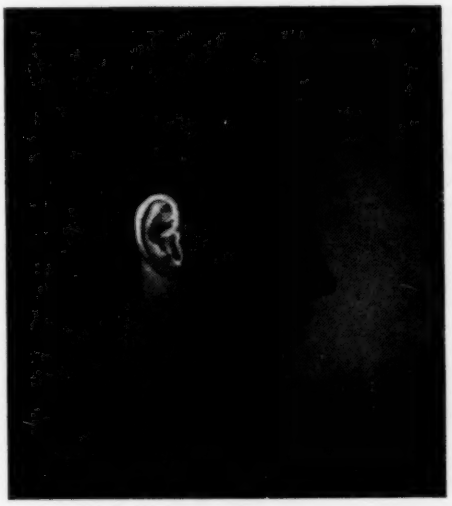

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RESPIRATORY FUNCTION DURING THE DAY IN COTTON WORKERS: A STUDY IN BYSSINOSIS

BY

C. B. McKERROW, M. McDERMOTT, J. C. GILSON, and R. S. F. SCHILLING

From the Pneumoconiosis Research Unit of the Medical Research Council, Llandough Hospital, Nr. Penarth, Glamorgan, and the London School of Hygiene and Tropical Medicine

(RECEIVED FOR PUBLICATION NOVEMBER 22, 1957)

Some of the workers in the dustier parts of a cotton mill (card- and blow-rooms) develop byssinosis. They experience tightness of the chest and breathlessness on Mondays or on the first day at work after an absence; these symptoms come on gradually, reaching a peak during the afternoon or early evening. In the early stages (Grade I) the workers feel quite fit by the next day; in the more severely affected the symptoms persist on Tuesdays, and even throughout the week (Grade II). Finally, disability may become permanent and severe (Schilling, Hughes, Dingwall-Fordyce and Gilson, 1955). In this study it was also shown that the ventilatory capacity of the lungs was related to the degree of byssinosis and was lower than in normal controls; in those with byssinosis it was also lower on Monday than Thursday.

The present work was done to study in more detail the short-term effect of mill dust on respiratory function, and to find which simple respiratory test was the most sensitive measure of this effect. We thought that measurement of the change in ventilatory capacity over one day might prove preferable to a comparison between Monday and Thursday by being less affected by variations in weather and other extraneous influences.

In Part I detailed studies on 12 mill workers with clinical byssinosis revealed a consistent pattern of change of ventilatory function within a single day, and in Parts II and III evidence has been obtained that these effects are specific to mill dust.

METHODS

Ventilatory Capacity

Ventilatory capacity was estimated from the volume expired in 0·75 second during a forced expiration, using an apparatus similar to that described by Gaensler (1951) but modified so that the timing cycle starts after the expulsion of the first 100 ml. of air. This reduced the error arising from differences in abruptness of starting expiration. The volume measurement was accurate to $\pm 1{\cdot}5\%$ and the timing to $\pm 2{\cdot}0\%$. The mean of three results following usually two practice attempts was taken, and multiplied by 40 to give the indirect maximum breathing capacity (indirect M.B.C.) shown by Kennedy (1953) to be highly correlated with and numerically similar to the maximum voluntary ventilation (M.V.V.). The physiological nomenclature is that agreed by a group of physiologists (Gandevia and Hugh-Jones, 1957).

The pneumotachogram was recorded using a large Lilly type flowmeter (Lilly, 1950) in which the differential pressure across a 4 in. diameter screen was measured by a capacitance manometer and recorded on a pen recorder. The system gave a linear response with flow rates up to 1,000 l./min.

The following measurements were made from the pneumotachograph records:—

(1) The peak expiratory flow during single forced expirations;

(2) the peak inspiratory and expiratory flows during voluntary hyperventilation;

(3) the maximum voluntary ventilation (M.V.V.) by integration of six breaths during hyperventilation.

The mean of two sets of three maximal expirations from full inspiration was taken to obtain the peak expiratory flow, and these were followed after a short rest by two sets of five maximal inspirations and expirations done " as deeply and as quickly as possible ". All subjects chose breathing rates over 60 breaths per minute. The last three breaths from each set were averaged to provide the peak inspiratory and expiratory flows during hyperventilation (peaks maintained over 10 m.sec.) and also the maximum voluntary ventilation.

Flow Resistance

The flow resistance of the lungs has two main components: (1) the resistance of the bronchial tree to the movement of air; (2) the frictional resistance involved in the movement of lung tissue.

Measurement of resistance requires simultaneous recordings of air flow and pressure, and the latter presents the greatest difficulty. The only method suitable for use in the present investigation was the " interrupter technique ", described originally by Neergaard and Wirz (1927) and elaborated by Vuilleumier (1944). This

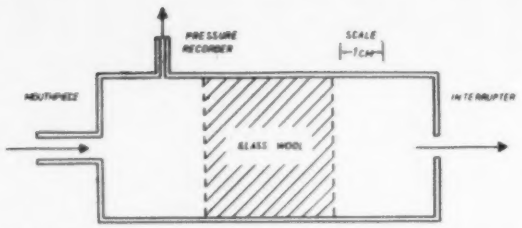


FIG. 1.—Airways resistance apparatus: diagram of the external resistance, the glass wool and interrupter orifice form R_E.

method is based on the knowledge that the volume of air in the alveoli is very large compared with that in the airways, hence, if during respiration the airflow at the mouth is instantaneously interrupted (for example, by a rapidly closing shutter in the breathing tube) pressure equilibration will take place throughout the lungs and the mouth pressure will rapidly rise to a value very close to the alveolar pressure before interruption. The resistance of the lung airways can be calculated from the air flow immediately before interruption and the " interrupter pressure ".

This technique was further simplified by Ainsworth and Eveleigh (1952), who designed a very ingenious instrument, using an external resistance to eliminate the separate measurement of air flow, and this principle is used in our instrument.

The subject breathes out at a constant flow rate Q (l./sec.) through the external resistance R_E (Fig. 1) and the pressure difference P_1 (cm. H_2O) is continuously recorded with a pen recorder.

Hence, $$P_1 = R_E Q^n \qquad (1)$$

(where $n = 1{\cdot}66$ and expresses the degree of turbulence in the external resistance and lung airways, and the pressure drop across R_E is 7·3 cm. H_2O at 1 l./sec.).

The air flow is then interrupted and the recorded pressure rises rapidly to the approximate alveolar pressure, P_2. The first pressure, P_1, is that necessary to maintain flow through the external resistance alone, and the second pressure, P_2, that necessary to maintain the same flow through the lung airways (R_L) and the external resistance, hence $P_2 - P_1$ is the pressure necessary to maintain the flow through the airways.

Therefore, $$P_2 - P_1 = R_L Q^n \qquad (2)$$

from (1) $$\left(\frac{P_2}{P_1} - 1\right) R_E = R_L \qquad (3)$$

R_E is a constant and its value is known, therefore from the measurements of P_1 and P_2 the lung airways resistance, R_L, can be calculated. If comparative measurements only are required, expression (3) need not be evaluated,

$\left(\frac{P_2}{P_1} - 1\right)$ being used instead.

This has been done throughout this paper and is called the airways resistance (A.W.R.) and the results expressed as " units ".

The absolute values may be obtained by multiplying the ratio $\left(\frac{P_2}{P_1} - 1\right)$ by the value of the external resistance at 1 l./sec. (7·3 cm. H_2O) when the lung airways resistance will be expressed in cm. H_2O (l./sec.) $^{1{\cdot}66}$.

Later work by Mead and Whittenberger (1954) suggests that the " interrupter technique " gives values of resistance which are closer to the total tissue and airways resistance than to those of the airways alone. The average value of 2·6 cm. H_2O at 1 l./sec. obtained on a group of laboratory subjects using an external resistance is almost identical with the figure obtained by Mead and Whittenberger using separate flow and pressure measurements. In a group of normal subjects the A.W.R. fell about 5% during the day ($0{\cdot}10 > P > 0{\cdot}05$). The mouthpiece resistance (0·1 cm. H_2O at 1 l./sec.) causes a small (about 10%) rise in the value for the lung airways resistance when compared with a large diameter mouthpiece (1 in. diameter).

In Part I, five measurements were made on expiration only over the flow rate 0·5 to 1·5 l./sec.; this was later increased to 12 measurements over the range 0·5 to 2·5 l./sec. (The standard error of a single set of 12

TABLE I

CARD-ROOM WORKERS WITH BYSSINOSIS IN MILL *A*

Subject	Sex	Age	Occupation	Grade of Byssinosis	Dyspnoea*	
					On Best Days	On Mondays
1	M	47	Stripper and grinder		I	I
2	M	24	Stripper and grinder		I	I
3	F	58	Draw frame tenter	I	I	II
4	F	64	Rover tenter		I	II
5	F	44	Slubber tenter		I	I
6	F	66	Draw frame tenter		I	I
7	M	44	Blowing-room		I	I
8	M	45	Stripper and grinder		I	I
9	M	61	Stripper and grinder		I	III
10	M	63	Cleaner	II	II	IV
11	M	57	Stripper and grinder		II	II
12	F	34	Slubber tenter		I	I

*Disability assessment of Schilling *et al.* (1955).

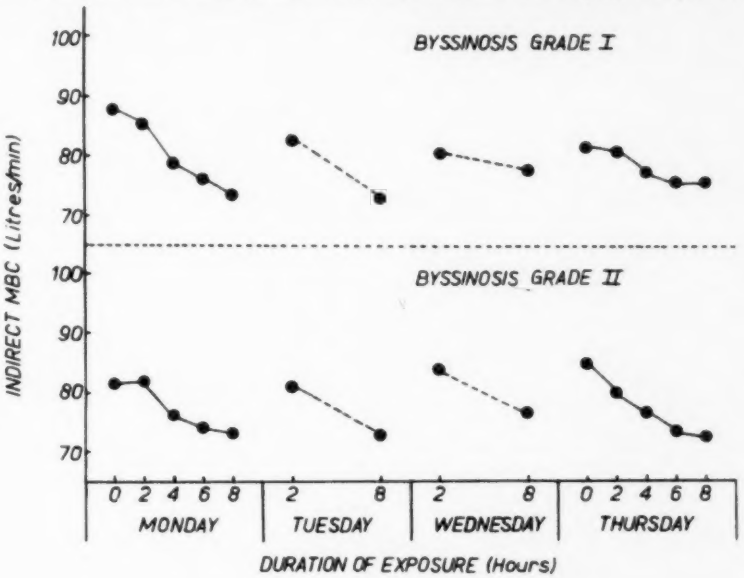
Grade I = normal
" II = able to keep up with normal men on level only
" III = unable to walk without stopping except at his own speed
" IV = only able to walk 100 yd. without stopping

readings in untrained individuals is about 11%.) Over this range the degree of turbulence in airways is approximately the same as that in the external resistance. However, one cannot extrapolate directly to obtain values of resistance at flow rates outside these limits.

The main importance of the resistance measurements lies in the fact that no maximal effort is required on the part of the subject, and the results are to a large extent independent of cooperation. This contrasts with all the other tests in this investigation.

All the physiological tests were made with the subjects seated. The indirect M.B.C. results were corrected to body temperature and pressure saturated with water vapour.

FIG. 2.—Daily change in indirect maximum breathing capacity in six subjects of each byssinosis grade in mill *A*. (The midday break, 12 to 1 p.m., was excluded from the period of exposure.)



PART I

Subjects with Byssinosis Exposed to Mill Dust

Procedure.—Twelve card-room workers from an Oldham mill (mill *A*) were selected as well-defined examples of Grades I and II byssinosis of both sexes (Table 1). The main studies on them were made from Monday to Thursday in one week although they had practised the tests on the previous Friday.

On Monday and Thursday all tests were done at 7.30 a.m. before the subject had entered the card-room, and again at 9.30 a.m., at 11.30 a.m., at 2.30 p.m., and at 4.30 p.m. On the Tuesday and Wednesday they were done only at 9.30 a.m. and at 4.30 p.m.

The indirect M.B.C. was measured first and this was followed after a rest of about two minutes by the pneumotachograph records. After a further short rest, the A.W.R. tests were done.

Results.—The results are as follows:

(1) *Indirect Maximum Breathing Capacity.*—The average changes in indirect M.B.C. during the day for the first four days of the week in those with Grade I and Grade II byssinosis are shown in Fig. 2, and for each subject on Monday and Thursday in Table 2. There is a nearly linear fall of M.B.C.

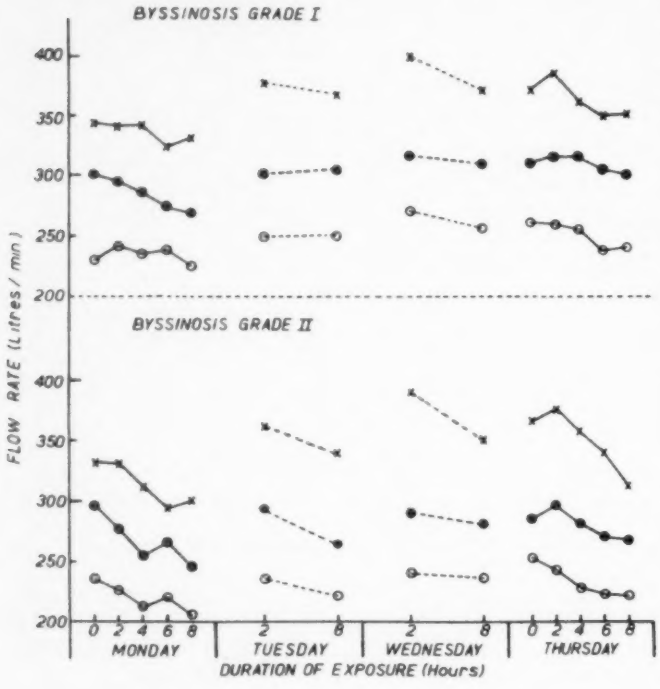
TABLE 2

CHANGE OF INDIRECT MAXIMUM BREATHING CAPACITY AND PEAK EXPIRATORY FLOW (SINGLE BREATHS) DURING HOURS OF WORK

Subject	Grade of Byssinosis	Change of Indirect M.B.C. (l./min./hour)†		Change of Peak Expiratory Flow (l./min./hour)†	
		Monday	Thursday	Monday	Thursday
1	I	− 2·10*	− 0·65*	− 8·33	− 4·79
2		− 1·78*	− 0·02	+ 1·93	+ 4·05
3		− 1·63*	− 0·72*	+ 1·35	− 3·95
4		− 3·10*	− 1·55*	− 6·38	− 6·97
5		− 0·37	+ 0·13	− 1·26	− 1·59
6		− 0·84*	− 1·49*	+ 1·00	− 6·13
7	II	+ 0·62*	− 0·69*	− 4·14	− 7·43
8		− 1·03*	− 0·71*	+ 1·79	− 2·62
9		− 3·34*	− 3·00*	− 6·19*	− 11·52*
10		− 3·80*	− 2·09*	− 6·13	− 8·37*
11		− 1·39*	+ 0·39*	—	—
12		− 0·71*	− 0·61*	− 6·50	− 1·45
Mean	I	− 1·64*	− 0·71*	− 1·95	− 3·23*
Mean	II	− 1·11*	− 1·12*	− 4·24*	− 6·28*

*Change significant at 5% level. †Regression coefficients.

FIG. 3.—Daily change in peak expiratory flow rate in single breaths (×), in peak expiratory flow rate during hyperventilation (●), and in peak inspiratory flow rate during hyperventilation (O).



during the whole of the working day and this is significant ($P < 0.05$) in all except one subject on Monday, and two on Thursday. Fig. 2 indicates that the subjects recovered partially overnight. The mean fall of 1·64 l./min./hour in Grade I on Monday is significantly greater than 0·71 l./min./hour on Thursday, whereas in Grade II the fall is almost identical on the two days.

(2) *Peak Expiratory Flow (Single Breaths).*—The peak expiratory flow during forced expiration is shown in Fig. 3 and Table 2. Each figure is the mean of the six observations. There is a tendency for the peak flow to fall during the day, but the trend is less constant than that seen in the indirect M.B.C. In fact, three subjects in Grade I and one in Grade II on the Monday showed a rise which was not statistically significant. There were only three statistically significant falls in the whole group on Monday and Thursday combined. In addition the average value of peak flow in most subjects tended to rise during the week—possibly a learning effect.

(3) *Inspiratory and Expiratory Peak Flow during Hyperventilation.*—The peak inspiratory flow is of interest as possibly giving an estimate of the change of inspiratory resistance. The flow during hyperventilation rather than single breaths was chosen as untrained subjects find a single forced inspiration difficult to do. Fig. 3 shows that there was greater variability in the pattern of change during the day and from day to day of the peak inspiratory flow than in the case of the indirect M.B.C. The peak expiratory flow during hyperventilation showed a trend generally similar to that measured on single breaths but the rise of the initial daily reading during the week was smaller. A comparison between the various tests is given in Table 3 where the change during the day is expressed as percentage per hour derived from the regression coefficients of the results grouped by byssinosis grade.

(4) *Maximum Voluntary Ventilation.*—The measurement of M.V.V. derived from the integration of six breaths recorded on the pneumotachograph showed a pattern of change very similar to the indirect M.B.C. and with a slightly greater fall during the day, but less differentiation between byssinosis Grades I and II (Table 3).

(5) *Airways Resistance.*—The average changes in resistance are shown in Fig. 4 and Table 3. In both groups there is an increase during the day, the changes being greater in Grade II than in Grade I. On Monday four out of six subjects in Grade I showed an increase in airways resistance, although the average change for the group is not significant. In Grade II four out of five subjects showed an increase during the day and the average change for the group is significant ($P < 0.05$). On Thursday the changes were again significant in Grade II but not in Grade I. The range of percentage changes is greater for resistance than for the M.B.C. and flow measurements, two subjects in Grade II showing an increase of more than 100%.

PART II

Control Studies

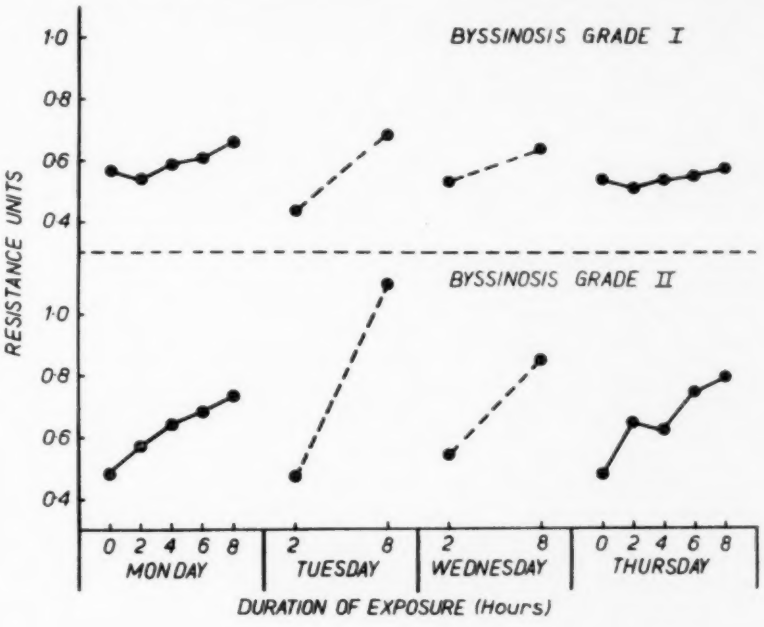
Subjects with Byssinosis Working away from Cotton Dust.—Of the 12 workers already studied, eight were chosen whose indirect M.B.C. had fallen considerably during the day. These people were examined again in two groups of four on two successive Mondays. On the first day one group did light work in the mill, but away from the card-

rooms, while the members of the other worked at their usual jobs in the card-room. On the second Monday the groups were reversed.

All the individuals again showed a reduction in the indirect M.B.C. when in the card-room and in all except one this fall was either reversed or reduced when away from it. The mean percentage fall in indirect M.B.C. of 19·7% when in dust (Table 4) is significantly different from that of 2·8% when working out of it ($0{\cdot}02 > P > 0{\cdot}01$).

The A.W.R. increased in only four of the individuals during the day's work in the card-room, but in all except one it fell during the day outside it. The mean difference in change on the two occasions was not statistically significant ($P > 0.1$).

FIG. 4.—Daily change in airways resistance in subjects of each byssinosis grade in mill *A*.



Effect of Adrenaline.—As a further demonstration that some active process was taking place in these subjects with byssinosis when working in the card-room, we tested the effect on the ventilatory capacity of the inhalation of neb.adrenaline et atropine co. (National Formulary) after the day's work. Six subjects were given the inhalations from a nebulizer for five minutes on a Monday at 4.30 p.m. and its effect was compared with that of a similar inhalation given on a Friday morning within two hours of starting work. In normal subjects little change in ventilatory capacity would be expected after adrenaline (Gilson and Hugh-Jones, 1955). On Monday the mean indirect M.B.C. of the group fell from 68·2 l./min. to 53·2 l./min. during the day's work but returned again to 65·6 l./min. after the adrenaline inhalation, and this was accompanied by subjective improvement in some subjects. On Friday the initial reading at 9.30 a.m. was 62·2 l./min. and the inhalation raised this to 67·8 l./min. The

TABLE 3

PERCENTAGE CHANGES IN VENTILATORY TESTS PER HOUR OF WORK

Test	Grade of Byssinosis	Monday		Thursday	
		First Reading (7.30 a.m.) (l./min.)	% Change/Hour	First Reading (7.30 a.m.) (l./min.)	% Change/Hour
Indirect M.B.C.	I	87·6	−1·87	81·7	−0·87
	II	81·9	−1·36	82·4	−1·36
Peak expiratory flow	I	344	−0·57	372	−0·87
	II	331	−1·28	366	−1·72
Peak inspiratory flow (hyperventilation)	I	230	−0·28	262	−1·07
	II	236	−1·17	253	−1·38
Peak expiratory flow (hyperventilation)	I	301	−1·23	321	−0·63
	II	296	−1·62	286	−0·98
M.V.V.	I	90·8	−2·06	96·8	−1·90
	II	91·8	−2·05	86·8	−1·65
		First Reading (resistance units)	% Change/Hour	First Reading (resistance units)	% Change/Hour
A.W.R.	I	0·57	+1·7	0·54	+1·1
	II	0·48	+7·6	0·48	+6·1

TABLE 4

CHANGES IN INDIRECT MAXIMUM BREATHING CAPACITY AND AIRWAYS RESISTANCE OF EIGHT SUBJECTS IN AND OUT OF CARD-ROOM ON A MONDAY

Time	Indirect M.B.C.				A.W.R.			
	In Card-room		Out of Card-room		In Card-room		Out of Card-room	
	l./min.	% Change	l./min.	% Change	Units	% Change	Units	% Change
8 a.m.	79·3	—	81·6	—	0·63	—	0·68	—
11 a.m.	71·9	− 9·3	83·7	+2·6	0·80	+22·8	0·62	−1·9
4 p.m.	63·7	−19·7*	79·3	−2·8*	0·84	+25·6	0·59	−7·8

*These figures differ significantly from one another ($0{\cdot}02 > P > 0{\cdot}01$).

rather low initial reading suggested that some bronchospasm was already present, confirming the trends during the week seen in Part I.

Cotton-workers without Byssinosis.—Twelve card-room workers from the same mill as those already described, and of similar ages and working conditions but without any symptoms of byssinosis, were seen three times on a Monday. Six showed a fall of ventilatory capacity, one a rise, and five little change during the day. Table 5 gives the mean results together with those for the subjects with byssinosis over a similar period of time for comparison. A small fall of 4·8 l./min. (6·0%) occurred which is not statistically significant ($0{\cdot}1 > P > 0{\cdot}05$). The fall is less than half that seen in those with byssinosis.

The airways resistance was measured in 10 cotton-workers without byssinosis (Table 6); the mean increase of 0·08 units (9·8%) is statistically insignificant ($P > 0{\cdot}5$). Further results of comparisons of those with and without byssinosis are given in Part III.

Coal-miners Exposed to Dust on the Coal-face.—Studies so far made strongly suggested that something in the mill dust or the job was causing changes in lung function but it was necessary to exclude the possibility that they were the result of the physiological or psychological effects of fatigue, or due simply to the irritation of a dust which was not pharmacologically active. The change in airways resistance suggests a cause other than fatigue, as little effort is needed for the test.

As a further check we studied a group of coal-face workers in a South Wales mine on a Monday morning at 7 a.m. before their shift, and again at 2 p.m. after it. Dust sampling in the mine showed that they were exposed to an average total dust concentration of 21·2 mg./m.^{3} which was about four times the concentration in mill *B* (see Part III). The comparison is given for total dust because we are probably concerned with coarse ($> 5\mu$) as well as fine dust. If the changes in the byssinotic subjects were related simply to the inhalation of inert dust, one would expect to see similar changes at least as great in the miners.

The group of 33 miners were all those available who were working on two coal-faces. Their average age of 29·6 years was considerably lower than that of the cotton workers. However, examination of the individual results of the miners showed no trend of change with age, and likewise the results

TABLE 5

CHANGES IN INDIRECT MAXIMUM BREATHING CAPACITY IN CARD-ROOM WORKERS IN MILL *A* ON A MONDAY

Time	No Byssinosis (12 subjects)		Grade I Byssinosis (6 subjects)		Grade II Byssinosis (6 subjects)	
	l./min.	% Change	l./min.	% Change	l./min.	% Change
9 to 9.30 a.m.	76·8	—	85·3	—	82·0	—
2 to 2.30 p.m.	74·0	−3·6	76·0	−15·0	74·1	−10·4
4.30 p.m.	72·0	−6·0	73·4	−15·4	73·2	−12·3

TABLE 6

CHANGES IN AIRWAYS RESISTANCE IN CARD-ROOM WORKERS IN MILL *A* ON A MONDAY

Time	No Byssinosis (10 subjects)		Grade I Byssinosis (6 subjects)		Grade II Byssinosis (5 subjects)	
	Units	% Change	Units	% Change	Units	% Change
9 to 9.30 a.m.	0·68	—	0·54	—	0·57	—
2 to 2.30 p.m.	0·73	+5·5	0·61	+14·4	0·68	+24·3
4.30 p.m.	0·76	+9·8	0·66	+21·6	0·75	+37·3

on cotton workers have shown no close relationship between age and the change of ventilatory capacity during a Monday. The average working time underground was 14·6 years. Twenty-three of the miners had normal radiographs, five had Category 1 and two Category 2 simple pneumoconiosis (including one with Category *A* complicated pneumoconiosis). Three were not examined radiologically.

Table 7 gives the average change of indirect M.B.C.

TABLE 7

CHANGES IN INDIRECT MAXIMUM BREATHING CAPACITY AND IN AIRWAYS RESISTANCE IN THE MINERS ON A MONDAY

Time	Indirect M.B.C. (l./min.) (33 subjects)	Airways Resistance (units) (19 subjects)
7 a.m.	131·8	0·45
2 p.m.	135·0	0·42
% Change	+3·8%	−5·5%

Change in M.B.C. is significant ($P < 0·05$).

in all subjects and of the A.W.R. in 19 (the maximum number who could be examined in the time available). The significant rise in M.B.C. of 3·8% and the fall in A.W.R. of 5·5% are in sharp contrast to the results for the cotton workers in mill dust. Similar slight increases in M.B.C. after work in coal-mines have been reported by Worth, Valentin, Venrath, Gasthaus, and Hoffmann (1956) and by Gielen (1957).

PART III

A Card-room Population before and after Dust Suppression

In another mill (mill *B*) which had a high prevalence of byssinosis in its card-room workers (37% in the two grades of byssinosis), vacuum dust extraction of a new type developed by the Shirley Institute (Ministry of Labour and National Service, 1957) was about to be installed on each carding engine. We therefore decided to see whether improvement in dustiness could be detected physiologically.

Clinical assessments of one card-room population were made and over 90% of the population agreed to cooperate in the initial studies during a Monday before the installation of the dust suppression equipment. Ten months later and three weeks after the completion of the installation there were 39 of the 51 card-room workers originally examined still at the mill. The same tests were repeated by the same observers.

The total dust concentration at the time of the first survey was 4·6 mg./m.^{3} and during the second after dust suppression 2·4 mg./m.^{3}

Table 8 shows the average change in indirect M.B.C. in all 51 subjects, and in A.W.R. in 27 at the time of the first survey related to byssinosis grade. In contrast to the finding in mill *A* where the subjects were selected on the basis of having undoubted byssinosis Grades I and II, or of being quite free from symptoms, there is in mill *B* an average fall in M.B.C. and rise of A.W.R. not closely related to clinical assessment of the severity of byssinosis. The changes in the groups as a whole are, however, significant ($P \simeq 0·001$ in the M.B.C. and $0·01 > P > 0·005$ in the A.W.R.).

In this comparatively large group, it is of interest to relate the absolute change in M.B.C. during the day to age. The relation appears extremely poor. The correlation did not approach significance ($r < 0·2$).

Table 9 gives a comparison of the changes on a

TABLE 9

CHANGES IN INDIRECT MAXIMUM BREATHING CAPACITY AND IN AIRWAYS RESISTANCE ON A MONDAY IN MILL *B* BEFORE AND AFTER DUST SUPPRESSION

	Time	Indirect M.B.C. (l./min.) (39 subjects)	Airways Resistance (units) (19 subjects)
Before Dust Suppression	8 a.m.	90·6	0·47
	4.30 p.m.	83·9	0·66
	% Change	−8·7%	+36·1%
After Dust Suppression	8 a.m.	90·6	0·51
	4.30 p.m.	88·1	0·50
	% Change	−3·7%	−2·4%

The change during the day before dust suppression is significantly different from the change after dust suppression in both tests : ($P < 0·05$ in the M.B.C. and $P < 0·01$ in the A.W.R.)

TABLE 8

CHANGES IN INDIRECT MAXIMUM BREATHING CAPACITY AND IN AIRWAYS RESISTANCE ON A MONDAY IN MILL *B* BEFORE DUST SUPPRESSION

Time	Indirect M.B.C. (l./min.)			Airways Resistance (units)		
	No Byssinosis (32 subjects)	Grade I (14 subjects)	Grade II (5 subjects)	No Byssinosis (15 subjects)	Grade I (8 subjects)	Grade II (4 subjects)
8 a.m.	88·0	94·9	72·7	0·50	0·55	0·47
4.30 p.m.	82·0	87·6	68·1	0·72	0·61	0·61
% Change	−7·9%	−8·2%	−9·3%	+39·1%	+20·8%	+29·8%

The changes during the day are significant ($P \simeq 0.001$) in the M.B.C. of the whole group of 51 subjects and in the A.W.R. ($0·01 > P > 0·005$) in the group of 27 subjects examined.

Monday before and after dust suppression in those subjects examined on both occasions. It can be seen that there is now less than half the change in the indirect M.B.C. and the change of airways resistance during the day has altered from a rise of 36% to a fall of 2%. These differences on the two occasions are significant ($P < 0.05$ in the M.B.C. and $P < 0.01$ in the A.W.R.).

DISCUSSION

Specificity of Lung Function Changes

The relationship of work or environment in the mill to lung function measured by two tests of ventilatory function has been demonstrated by removing eight subjects from the card-room for a day, when no significant changes were observed. As the exertion was less when out of card-rooms the effect of fatigue could not be excluded, but the findings in a group of miners working on the coal-face show that neither the fatigue of heavy exertion nor the inhalation of an inert dust such as coal could be responsible for the changes. We are, therefore, justified in concluding that the mill dust is the cause of the respiratory impairment, and that it contains some pharmacologically active constituent. The reduced effect on lung function in mill *B* after the dust levels had been lowered shows that a quantitative dose response relationship exists. The form of this relationship is under investigation.

Relation of Respiratory Changes to Degree of Byssinosis and to the Day of the Week

In the initial group of subjects selected as well-defined examples of byssinosis Grades I and II, and the group without any symptoms of byssinosis, there was a fairly clear-cut relationship between the degree of byssinosis and the change taking place during a Monday. However, in the representative sample of all card-room workers in mill *B* no clear relationship persists. The difference may be the result of the difference in selection. There seems no doubt that those without clear-cut byssinosis do frequently also show some change of ventilatory function during the day. Thus, physiological tests reveal changes before disability is detectable clinically.

The greater change in ventilatory capacity on Monday than on Thursday in Grade I is in accord with the clinical symptoms characteristic of the group. It seems possible that it is the rate of change which is detected by the subject. In Grade II the rate of fall is much the same on Monday and Thursday and it is a feature of this grade that the symptoms persist throughout the week.

The nearly linear decline of the maximum breathing capacity during the Monday suggests that the type of response is very different from that observed in the asthmatic. Further work is in progress to relate the dust exposure of the individual during his working day to the physiological changes on that day. It is probable that some of the variability of the response seen in the subjects reported here is the result of actual variations in dose received, because the time actually spent in the card-room varies from man to man and from job to job in this part of the mill.

The Pharmacological Mechanism of the Changes

It is not yet possible to state how the active constituent produces its effect—whether by causing oedema or broncho-constriction, or both. The nearly complete reversal of the changes by adrenaline does not permit separation of these two possible effects. Preliminary studies using mepyramine do not suggest that the effect is readily reversed by anti-histaminic drugs.

The incomplete recovery of ventilatory capacity over a single night is to be expected because elimination of dust from the bronchial tree takes more than 12 hours. The cause of the smaller response in the Grade I subjects on Thursday than on Monday is uncertain. It is improbable that it is the result of a lower dust concentration on Thursday because extensive studies in other mills have shown that there is no general trend for the dust concentration to fall during the week, nor do the results in the Grade II subjects suggest it in this instance.

The finding that the airways resistance returned to normal while the indirect M.B.C. was still affected when the dust level was reduced from 4·6 mg./m.^{3} to 2·4 mg./m.^{3} needs comment. The A.W.R. is a less sensitive test than the indirect M.B.C. when the deviation from normal is small. But when gross changes are present the rise in the A.W.R. is more impressive than the fall in M.B.C. This is well seen in Figs. 2 and 4 where the rise of A.W.R. during the day in the Grade II cases is very marked.

It is also possible that the change in size distribution of the dust brought about by the dust suppression equipment and which preferentially removes the larger respirable sizes may be important. The A.W.R. may be more affected by changes occurring in the larger airways in which the larger particles are deposited. Much more work is needed to elucidate the pharmacological mechanism fully.

The present work cannot exclude Prausnitz' view (Prausnitz, 1936) that the pathological changes specific to the disease are thickening of the alveolar walls from irritating soluble proteins in the cotton dust, but the reversible physiological effects which

we have found cannot be ascribed to this pathology. Some of the subjects showing the largest change of airways resistance have also been hoarse towards the end of the working day, which further indicates that the active substance may be affecting the upper respiratory tract.

Choice of Tests

The indirect M.B.C. was the most stable test and showed the most consistent change with the duration of dust exposure (Fig. 2), although the maximum voluntary ventilation derived from the integrated pneumotachogram showed a slightly greater fall during the day in those with byssinosis (Table 3). However, we did not choose this test for the studies in Parts II and III because it requires more effort from the subject and its analysis is much more laborious. The peak expiratory flow rate on a single breath was unsatisfactory because of its variability from reading to reading, and its tendency to increase during the week to values higher than the initial one on Monday. Although the interrupter method of measuring the airways resistance may include a part of the tissue viscous resistance as well as the air flow resistance it was used as the only method at present possible for application in the field. The test also has the great advantage that as it requires no maximal effort on the part of the subject, it is most unlikely to be affected by fatigue or cooperation and so provides valuable additional evidence of the validity of the changes of function in the lung. The indirect M.B.C. and A.W.R. results are not very highly correlated, but in the present state of knowledge of the mechanics of respiration it is not possible to assess the full physiological significance of either test. The change of airways resistance expressed either in absolute units or as a percentage of the initial reading is greater than for the indirect M.B.C. but there are also more individuals who give inconsistent readings.

SUMMARY

Twelve subjects selected clinically as having well-defined Grades I and II byssinosis were studied at their work in the card-rooms during each day throughout a week. The indirect maximum breathing capacity (indirect M.B.C.) fell nearly linearly during the day. On Monday the fall in Grade I was 1·6 l./min./hr. and in Grade II 1·1 l./min./hr. On Thursday the fall was similar in Grade II but less marked in Grade I. The airways resistance (A.W.R.) measured by an interrupter technique increased on Monday by 1·7%/hr. in Grade I, and 7·6%/hr. in Grade II. Twelve card-room workers without byssinosis showed changes of M.B.C. and A.W.R. less than half as great as those with byssinosis.

Similar changes were observed in a complete card-room population but the relationship of the change to the grade of byssinosis was less clear cut.

The peak expiratory flow on forced expiration, and the inspiratory and expiratory peak flows on hyperventilation showed similar but less consistent changes.

Removal of subjects from the card-room prevented the changes. Also, 39 workers in another card-room studied before and after the installation of dust suppression equipment showed that reducing the dustiness reduced the fall of ventilatory capacity.

A group of coal-miners was examined before and after a shift on a coal-face where the dust concentrations were about four times as high as those in the card-room. There was an average small rise in M.B.C. and a fall in A.W.R. which contrasted sharply with the findings in cotton-workers.

We conclude that there is a pharmacologically active constituent in the mill dust causing the changes in ventilatory capacity. The mechanism of its action is discussed.

We should like to thank the staff and workers of the cotton mills and of the coal-mine whose cooperation made this study possible.

We are grateful also to many of our colleagues, especially to Mr. P. D. Oldham and Miss Barbara Snow for statistical help, to Dr. I. T. T. Higgins who did part of the clinical examinations, to Mr. S. A. Roach for the dust estimations, to Dr. R. Routledge, of the Medical Service of the National Coal Board, for assistance in the examination of the miners, and to Miss Margaret Collins for technical help.

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A HISTOLOGICAL STUDY OF THE LUNGS IN 52 CASES OF CHRONIC BERYLLIUM DISEASE

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Beryllium disease is a term used to describe the systemic effects of exposure, usually by inhalation, to beryllium and certain of its compounds and it can be subdivided into an acute and a chronic variety. This paper deals with the histological findings in the lungs in chronic beryllium disease. I agree with Hardy (1956) that the alternative term "chronic pulmonary beryllium disease" is unsuitable as it tends to obscure the essentially systemic nature of the disease, though the primary manifestations are usually in the lung.

Beryllium was first identified by Louis Nicolas Vacquelin in 1797. Until recently it was valued only as a component of precious stones but it is now used increasingly in industry, for example, in the production of such metal alloys as stainless steel and chromium and for the screening of uranium in atomic power stations. Other occupations where beryllium is a risk are the making of cathode tubes and *x*-ray machine windows, ceramics, beryllium extraction from ore, and certain experimental work. Beryllium has not been used since 1948 in the manufacture of fluorescent lamps.

Beryllium was soon found to produce toxic effects on inhalation and the earlier papers describe the acute manifestations of a metal-fume type of illness (Weber and Engelhardt, 1933; Fabroni, 1935; Gelman, 1936; Berkovitz and Israel, 1940). One of the earliest North American reports is that of Van Ordstrand, Hughes, and Carmody (1943) who described three acute cases. The earliest reports of a chronic pulmonary disease caused by beryllium came from the U.S.A. (Hardy and Tabershaw, 1946; Gardner, 1946; Higgins, 1947). The disease was the subject of a Saranac Symposium (Vorwald, 1950) and this report provides an excellent summary of knowledge up to that date. Since then a beryllium case registry has been started by Hardy (1955a) which up to date (personal communication) includes 500 cases, 287 chronic and 213 acute, with an overall mortality of 27%. Very few British cases have been reported. The first was by Agate (1948), an example of the chronic type, in a physicist working with fluorescent lamps. Royston (1949) has reported the only acute case to occur in Britain. Sneddon (1955) described a chronic case in a woman of 25 working with 2% beryllium-copper alloy. The only other report in the British literature is of a skin granuloma caused by a fluorescent tube fragment (Lederer and Savage, 1954). There are two other unpublished British chronic cases, namely, by Teare (1955) in a fluorescent lamp worker and by Rannie (1956) in an experimental chemist.

Materials and Method

This study is based on the histological examination of material from 52 cases, 49 American, and three British, of which 37 were necropsies and 15 biopsies. When death occurred it followed increasing dyspnoea terminating in cor pulmonale. In a few cases large lung sections were examined. All the cases were examples of chronic beryllium disease. These cases meet Hardy's (1955b) requirements for diagnosis, *viz.*, they all had had a definite exposure to beryllium, a characteristic granulomatous change, and in 27 cases beryllium was demonstrated in the lungs and/or urine.

Method of Exposure

The mode of exposure and distribution of the cases may be seen in Table 1. The duration of exposure varied widely from two months to 10 years, and a similar interval may exist between the end of exposure and death. There is also a wide variation in the latent interval between initial exposure and onset of disease. The amount of beryllium in the lungs ranged from 0·002 to 435 μg./100 g. dried lung, determined spectroscopically (Vorwald, 1950).

TABLE 1
MODE OF EXPOSURE OF 52 CASES EXAMINED

Occupation	Total
Fluorescent lamp industry	18 (1)*
Living near Be. plant (neighbourhood cases)	10
Beryllium alloy workers	9
Beryllium factory worker (type of work unspecified)	6
Laboratory workers	4 (2)
No details of exposure	2
Cathode tube factory	1
Ceramic factory	1
Glass factory	1

*British cases in brackets.

There was no correlation between these figures and the type or extent of the disease. It is of interest that 10 cases were " neighbourhood " ones with indirect exposure to beryllium, such as living down wind of a beryllium factory, washing beryllium workers' clothes, and fishing in the vicinity of a beryllium factory. Examples of such cases are described by DeNardi, Van Ordstrand, and Curtis (1952). Included in this group was a child of 7.

Age and Sex

The age was available in 46 cases (Fig. 1), ranging from 7 to 64 years. There were 34 men and 18 women for those whose ages were known, and the age distribution of the sexes was similar.

Results

No difference was discovered between the American and British cases either macroscopically or microscopically.

Gross Anatomy.—The lungs show interstitial fibrosis and in some instances scattered firm nodules a few millimetres in diameter. Emphysema may occur but since the majority of dilated air spaces are thick-walled, " cystic change " is a preferable term. The pleura is usually thickened. Hilar glands may be slightly enlarged and usually show areas of fibrosis. These features are not diagnostic (Fig. 2).

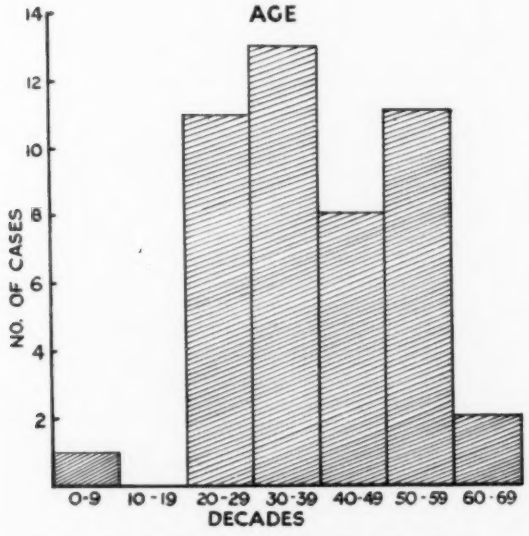

FIG. 1.—Age distribution in 46 cases of beryllium disease.

FIG. 2.—Gough-Wentworth large left lung section from a female fluorescent lamp worker. (×5/6) showing diffuse fibrosis and cystic change.

Histological Findings.—The essential lesion is that of a non-caseating, sarcoid type of granuloma situated in the interstitial tissue of the lung and tending to remain discrete (Fig. 3).

The distribution of the granuloma was found to be mainly septal, subpleural, peribronchial, and perivascular, often at the margins of secondary lobules.

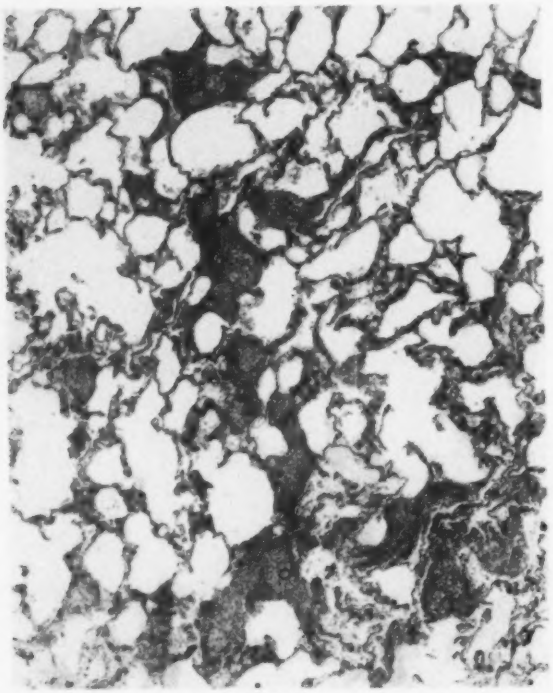

FIG. 3

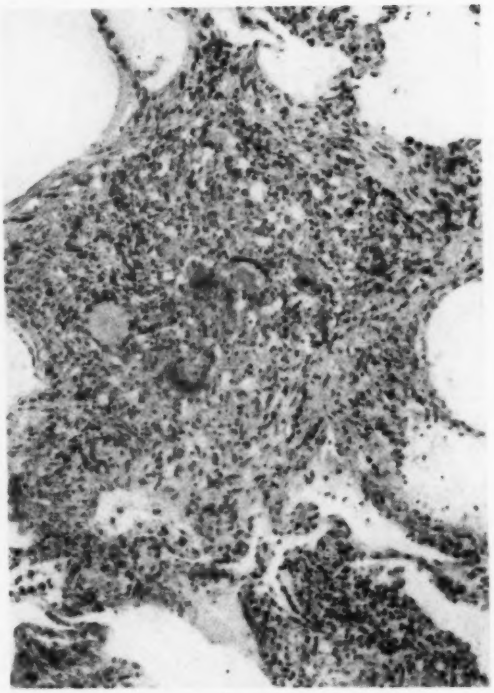

FIG. 4

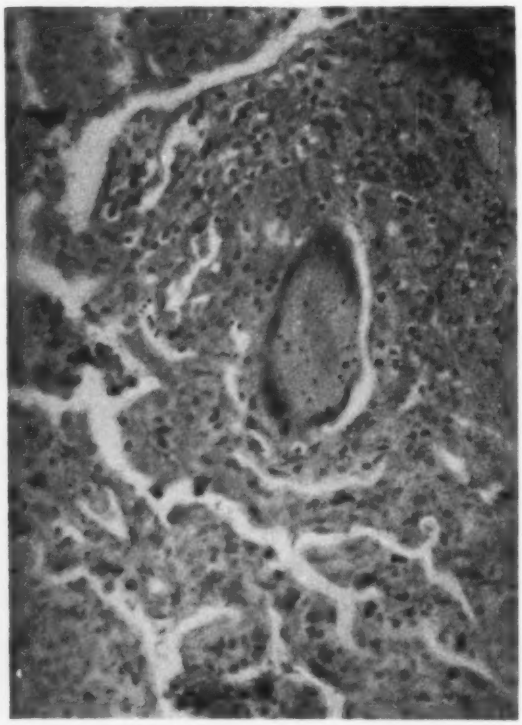

FIG. 5

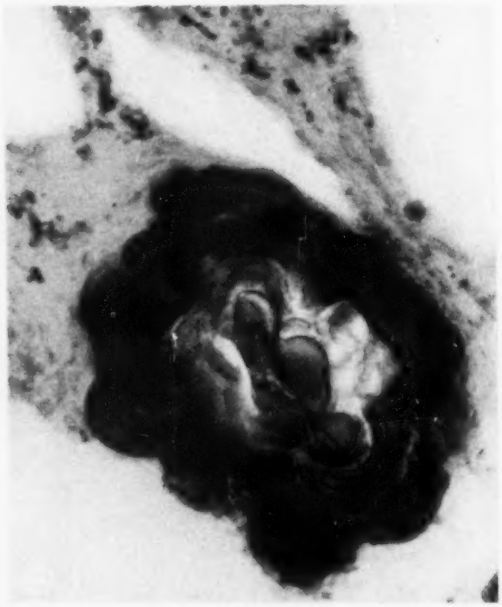

FIG. 6

FIG. 3.—P.T.A.H. × 29. Distribution of lesion in interstitium of lung.

FIG. 4.—Haematoxylin and eosin × 105. Early lesion.

FIG. 5.—Haematoxylin and eosin × 300. Giant cell with central condensation.

FIG. 6.—Haematoxylin and eosin × 300. Conchoidal (Schaumann) body.

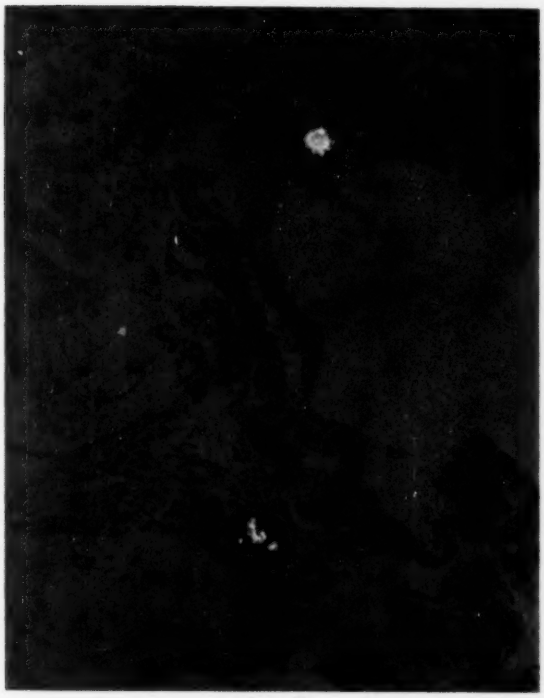

FIG. 7

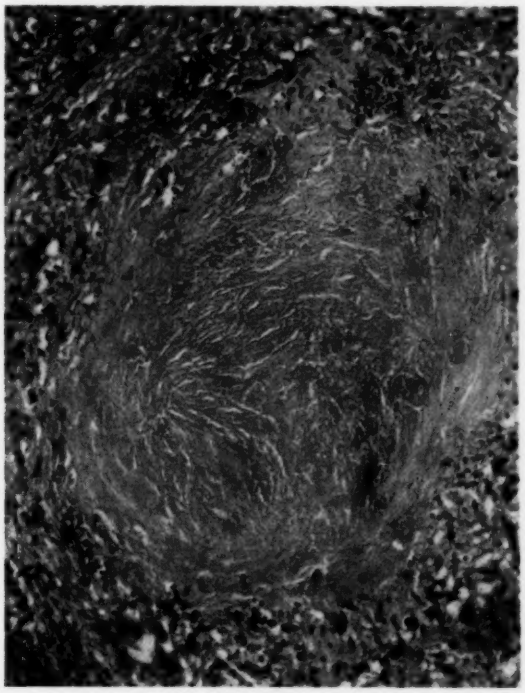

FIG. 8

FIG. 9

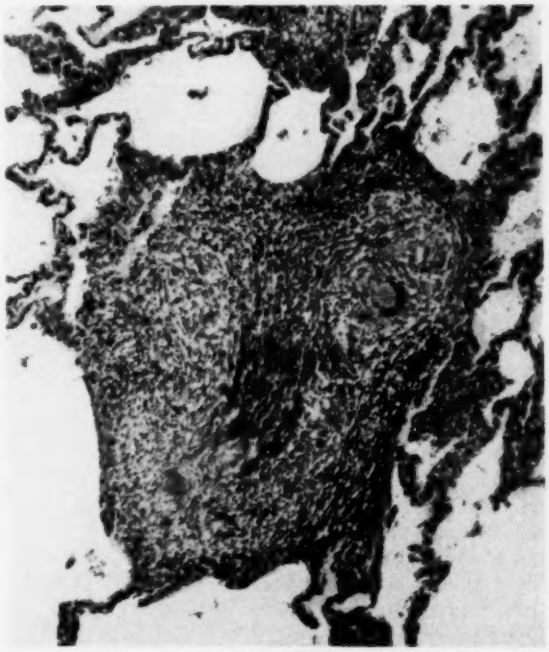

FIG. 10

FIG. 7.—Unstained, polarized × 105. Birefringent crystals.
FIG. 8.—Haematoxylin and eosin × 130. Hyaline change.
FIG. 9.—Reticulin × 80. Hyalinized granuloma.
FIG. 10.—Van Gieson × 80. Hyalinized granuloma.

The least complex, smallest, and so probably the earliest, lesions consisted of a loose collection of epithelioid cells surrounded by an ill-defined zone of lymphocytes and occasional plasma cells (Fig. 4); eosinophils were absent. As the granuloma increases in size and so probably matures, Langhan type giant cells appear, formed probably by a fusion of epithelioid cells, and occurred in 86% of cases.

Three types of inclusion bodies may be seen, usually in giant cells and occasionally in epithelioid cells, namely, asteroid bodies, conchoidal (Schaumann) bodies, and crystals.

Asteroid bodies were infrequent and had the same appearance as in Boeck's disease, occurring commonly in giant cells or rarely in epithelioid cells. A possible precursor stage was noticed in that some giant cells showed condensation of the central cytoplasm with increased eosinophilic staining (Fig. 5).

Conchoidal bodies were found in the lesions, but only when giant cells were also present. As the term implies they are shell-like, concentrically laminated calcified bodies, deeply basophilic (Fig. 6). They appear to arise and grow in giant cells and may finally disrupt the cell and become extracellular. As an extracellular structure they may then stimulate the production of foreign-body type giant cells. They measure up to 50μ in diameter and were present in 42% of cases.

Crystals may be of two types. Cholesterol crystals were seen in some of the older lesions and identified as empty clefts having been dissolved in paraffin embedding. Occasionally they do not dissolve and remain outlined by calcium and iron salts. The second type of crystals always resists paraffin preparation and persist as brilliantly birefringent single or clumped entities (Fig. 7). They range in size from 3 to 10μ, in their long axis, are usually plate-like, may be spiculated, only rarely needle-shaped, and always have a definite sharp edge. They were present in 46% of cases and it is of interest that 80% of conchoidal bodies contained these crystals.

It is considered that the cellular lesion is an early phase of the granuloma which becomes finally replaced by fibrous tissue. This is based on the generally accepted observations of human disease and animal experiments that a collagenized lesion may be preceded by reticulin formation which is preceded by a cellular lesion. The central epithelioid cells are progressively obliterated by interlacing strands of hyaline material (Fig. 8), which was seen in 52% of cases. There is no definite evidence of fibrinoid change in the granuloma. Hyalinization may be distinguished from true caseation by the absence of granularity and of the intermediate basophilic stage as seen in the necrosis of tuberculosis. In nine cases the hyaline material showed a tendency to whorling which may be confused with that of a silicotic nodule, but it is of interest that in seven of these silica exposure could not be excluded. The staining reaction of the hyaline material revealed increased reticulin formation with age (Fig. 9) and the development of collagen (Fig. 10). It was negative for amyloid staining, was sometimes faintly positive with P.A.S., and usually positive with molybdate (Pearce) for phosphate. Apart from the conversion of individual lesions into collagen there is a generalized interstitial fibrosis. It is noteworthy that in every case either a cellular or hyalinized granuloma was found, so assisting in a correct diagnosis. The interstitial mural cellular infiltration described by Schepers (1955) was inconspicuous and of no diagnostic value.

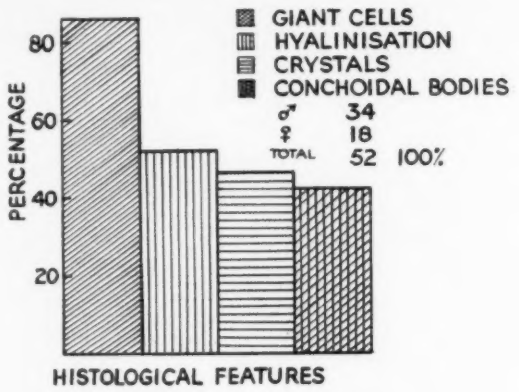

FIG. 11.—Overall percentages of histological features.

The granulomata in hilar glands showed identical features and similar hyaline replacement but rarely progressed to adult collagen. The appearances were not always easy to distinguish from healed tuberculosis.

A statistical test (χ^2) shows no difference in the incidence of giant cells, hyaline change, crystals, or conchoidal bodies in the two sexes. The overall incidence of these features may be seen in Fig. 11.

There was no difference in the incidence of any histological feature under or over 40 years of age (Table 2).

TABLE 2

THE RELATIONSHIP OF HISTOLOGY TO AGE

Histology	Under 40 Years (100% = 25 cases)	Over 40 Years (100% = 21 cases)
Focal granuloma	100% (25)	100% (21)
Interstitial fibrosis	100% (25)	100% (21)
Giant cells	84% (21)	85% (18)
Crystals	48% (12)	47% (10)
Conchoidal bodies	48% (12)	38% (8)
Hyaline change	52% (13)	52% (11)

No statistical correlation was found between the presence of any histological lesion and the length of exposure or duration of the disease. Approximate figures only were available to the author in a proportion of the cases so that the detailed tables are not included.

Emphysema was not a notable finding in any of these cases, and focal emphysema as seen in coalworkers was not observed (Gough, 1947; Heppleston, 1951).

Alveolar cell proliferation and metaplasia were inconspicuous (Jones Williams, 1957) which is at variance with Schepers' (1955) finding. There were no noteworthy changes in bronchial epithelium. Foam cell clusters and lobular septal cell proliferation, as described by Schepers, Durkan, Delahant, and Creedon (1957) occurring in rats inhaling beryllium, were also inconspicuous and there was no evidence of neoplastic change.

Vascular changes were inconspicuous. There was no evidence of an acute arteritis. Endarteritis obliterans was seen occasionally in some areas of fibrosis.

Discussion

It is apparent that the histological appearances of the granuloma produced by beryllium closely resemble those seen in Boeck's sarcoid (Hardy and Tabershaw, 1946; Dutra, 1948; Vorwald, 1948). While tuberculosis is often quoted as the important aetiological agent in Boeck's sarcoid, many other agents will produce the same histological lesion, *e.g.*, syphilis, leprosy, histoplasmosis, post-traumatic lesions (King, 1946) or lymph glands in drainage areas of malignant disease (Nadel and Ackerman, 1950). Glass (Ayres, Ober, and Hamilton, 1951) and paradichlorobenzene (Weller and Crellin, 1953) have also been incriminated. Gardner (1937) produced an identical lesion with inhaled silica in guinea-pigs. This is of interest in that the beryllium phosphors used in fluorescent lamp manufacture did contain silicates, zinc manganese beryllium silicate, magnesium silicate, zinc silicate, and varying amounts of free silica in the form of crystobalite. It is therefore imperative to obtain a detailed environmental and occupational history from all patients with suspected Boeck's sarcoid to determine any mineral exposure, especially to beryllium and possibly to silica. Nine cases (17%) in the present series showed whorled silicotic type nodules. The beryllium phosphors used in lamp manufacture consist mainly of silicates. Silicates produce a non-specific type of fibrosis and not the true whorled fibrosis produced by free silica, thus it is probable that in these nine cases the silicotic nodules were produced by a mixed exposure to free silica and beryllium rather than to the small amount of free silica in beryllium phosphors. Four of the nine cases had such a mixed exposure; three were brass foundry workers and one a chemist who had worked with quartz powders. Unfortunately, very few figures are available of the amount of silica in the lungs of this series. Gardner (1946) in 12 cases found low ash values varying from 1% to 3% (silicosis 3% to 34%) with a maximum silica in the ash of 4·36% (silicosis 7·29%). It is also recognized that tuberculosis can produce a whorled silicotic type nodule. In none of these 52 cases was there evidence of active tuberculosis. Further, the frequency of Mantoux-positive reactors in beryllium disease does not differ from that seen in the general population (Hardy, personal communication). It is therefore unlikely that tuberculosis was the cause of the silicotic type nodules in these patients. McLaughlin (1955) states that beryllium and silica are no longer used in fluorescent lamp manufacture and this has been true in the United States since 1949 (Hardy, 1955b).

The complete similarity of American and British cases both macroscopically and histologically is noteworthy. It is, however, surprising that so few cases have been reported in Great Britain and probably reflects the small number of exposed workers compared with the number in America and possibly missed cases and/or better industrial hygiene.

About 80% of cases of Boeck's sarcoid collected by Siltzbach (1955) were under the age of 40, compared with 48% in this series of chronic beryllium disease. This represents the age scatter in the cases at risk. The age of the patient did not influence the incidence of any histological feature.

The prognosis shows a considerable divergence. Hardy (personal communication) states that there is a 27% case mortality rate in chronic beryllium disease while Löfgren (1953) expressed the majority opinion that about 90% of cases of Boeck's sarcoid recover completely. Hardy (1956) discusses the differential clinical features of beryllium poisoning and sarcoidosis.

In Boeck's sarcoid the sexes are equally affected (Longcope and Freiman, 1952). In the present series 30% of the cases were women.

Dutra (1948) and Vorwald (1948) describe emphysema as being a frequent finding. The paucity of emphysema in the present cases is notable but may be because the complete lungs were seldom available for study. The material was, however, suitable for the evaluation of focal emphysema but this was absent. So beryllium and silica, unlike coal, do not produce focal emphysema. This is probably a manifestation of the degree of fibrosis, as very little collagen is seen in simple coalworkers' pneumo-

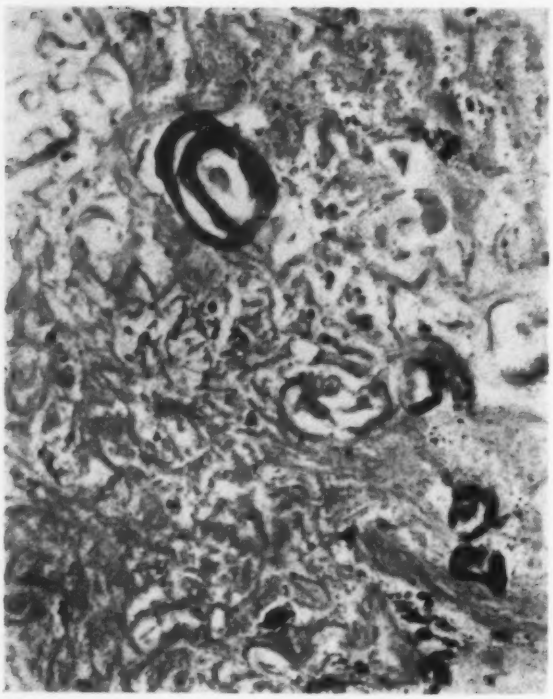

FIG. 12.—Haematoxylin and eosin × 520. Conchoidal body in tuberculosis.

FIG. 13.—Haematoxylin and eosin × 540. Conchoidal body in silicosis.

coniosis compared with a moderate amount in chronic beryllium disease and an excess in silicosis.

It is difficult to prove the exact nature of the hyaline change. It is emphasized that it is probably a gradual process and unlike the rapid necrosis of tuberculous caseation. It is, however, similar to the change seen in Boeck's sarcoidosis. The hyaline change is unlikely to be due to any specific arterial change; the occasional vessel showing endarteritis might as well be *post hoc* as *propter hoc*.

Asteroid bodies were uncommon in these cases and are of no assistance in diagnosis as they are often seen in other conditions, for example, in Boeck's sarcoid (Longcope and Freiman, 1952), in retention cyst of the breast, and in sebaceous cysts (Hirsch, 1935). Ricker and Clark (1949) state that they are commoner in tuberculosis, leprosy, histoplasmosis, schistosomiasis, and lipoidal granulomata than in Boeck's sarcoid.

Conchoidal bodies were found in 42% of these cases compared with Dutra's (1948) series where they occurred in 11 out of 13 cases. They are common in Boeck's sarcoid and occur in tuberculosis (Schaumann, 1941) and so again are not a diagnostic feature. Fig. 12 illustrates a conchoidal body in tuberculosis and Fig. 13 one in a silicotic nodule. Similar bodies are also described in multiple myeloma of the kidney (Apitz, 1940). Doniach and Wright (1951) described them in pituitary granuloma.

Cholesterol crystals are also non-specific and are often found in any area of tissue necrosis.

Birefringent crystals have been described in Boeck's sarcoid (Teilum, 1949; Cid, 1950; Engle, 1953; Longcope and Freiman, 1952), but their exact nature is still a matter of dispute. These crystals are identical with those found in the present series and so are not a diagnostic feature of chronic beryllium disease.

It is of interest that the histological findings—focal granuloma, interstitial fibrosis, hyaline change, giant cells, conchoidal bodies, and birefringent crystals—were not influenced by the length of exposure or the duration of illness.

The clinical features of a positive beryllium patch test (DeNardi, Van Ordstrand, Curtis, and Zielinski, 1953) and the development of a systemic disease after the inhalation of very small amounts of beryllium compounds favour the contention that the disease is a manifestation of hypersensitivity. However, in the absence of definite fibrinoid change, eosinophilia, and acute arteritis, the histological evidence does not support this theory.

Summary

The histological features of 52 cases, 49 American and three British, of chronic beryllium disease affecting the lungs are described. There was no difference between the American and the British cases. The histological lesion begins as a focal granuloma with a gradual transition to fibrous tissue and an associated interstitial fibrosis. The features are indistinguishable from Boeck's sarcoid. Thus for diagnosis a history of beryllium exposure and the demonstration of beryllium in tissues are essential. The following histological features and their incidence are described and discussed: Focal granuloma (100%), interstitial fibrosis (100%), giant cells (86%), hyaline change (52%), birefringent crystals (46%), conchoidal (Schaumann) bodies (42%).

Most of this material was collected during the tenure of a British Empire Cancer Campaign American-British Exchange Fellowship.

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THE EFFECT OF DIAMOND DUST ALONE AND MIXED WITH QUARTZ ON THE LUNGS OF RATS

BY

E. J. KING, M. YOGANATHAN, and G. NAGELSCHMIDT

From the Postgraduate Medical School, London, and the Safety in Mines Research Establishment, Sheffield

(RECEIVED FOR PUBLICATION DECEMBER 7, 1957)

Diamond, the hardest of all minerals, was classed as an inert material, similar to anthracite and corundum, by Gardner (1938) on the basis of intravenous injection experiments in rabbits. By intraperitoneal injection into mice Bovet (1952) produced collagenous nodules in places where much diamond dust was accumulated. But it took six months to one year for such nodules to form as against a few weeks for quartz of similar size.

Schiller (1955) injected diamond dust intraperitoneally into mice, alone and combined with silicic acid in the form of " aerosil ". The diamond dust produced only very slight fibrosis of the tissues, but laminated fibrous granulomata were formed after 60 days in the animals injected with silicic acid *plus* the diamond dust, on which Schiller supposed the silicic acid had been adsorbed.

Pure coal dust injected intratracheally into the lungs of different animals produces no other pathological result than the formation of a very few reticulin fibres within focal accumulations of the dust (Belt and King, 1945). Small amounts of free silica dusts (quartz, tridymite) are partly or wholly eliminated from the lungs into the lymph nodes and therefore produce little or no fibrosis in the lungs, but when these small amounts of free silica dusts are combined with large quantities of coal dust they produce more fibrosis in the lungs than the apparent sum of the two of them taken separately (Ray, King, and Harrison, 1951; Attygalle, King, Harrison, and Nagelschmidt, 1956). The same result was obtained with graphite, and we have now repeated the experiment with diamond dust alone and admixed with small amounts of quartz.

Experimental

Five experiments were set up as follows:—

(1) 100 mg. diamond dust
(2) 2 mg. quartz dust
(3) 5 mg. quartz dust
(4) 100 mg. diamond dust + 2 mg. quartz
(5) 100 mg. diamond dust + 5 mg. quartz dust.

All the substances were injected intratracheally.

The diamond dust was purchased as " diadust " (pure diamond powder—grade PMO/2).

The quartz dust was prepared from Madagascar quartz crystals, containing 99·6% SiO_2. The fraction 0·5-2μ was prepared by repeated sedimentation in water after grinding the material in a mechanically driven agate mortar. The silica solubility of this fraction was 13·5 mg. SiO_2 per 100 ml. in Ringer solution.

The size distributions of the diamond and quartz dusts are given in Table 1.

TABLE 1

PARTICLE SIZE DISTRIBUTION OF DIAMOND AND QUARTZ DUST

Size (μ)	Diamond (%)		Quartz (%)	
	By No.	By Mass	By No.	By Mass
0·08—0·11			0·8	
0·12—0·16	0·4		3·4	
0·17—0·23	7·1	0·2	4·7	
0·24—0·32	14·1	0·8	3·8	
0·33—0·45	22·8	3·4	3·4	0·1
0·46—0·64	23·5	10·5	2·4	0·2
0·65—0·9	21·5	26·9	19·8	4·5
1·0 —1·3	7·6	27·0	31·7	19·9
1·4—1·8	2·5	25·0	24·1	43·1
1·9 —2·6	0·2	6·2	5·7	28·7
2·7 —3·6			0·2	3·5
Specific surface (m^2 per g.)	2·5		2·0	
Mean volume-surface diameter (D_{VS})	0·89		1·46	

The dust suspensions were prepared for injection by dispersing the required amount of the dust, or the dust mixture, in physiological saline solution in a glass tissue grinder. The suspension was sterilized by autoclaving, and 5% of fresh sterile rat serum added to it. The dust suspensions were prepared on the day of injection, and were kept continually agitated on a mechanical shaker until used.

The rats used, seven males for each experiment, were of the black and white hooded variety supplied by the Medical Research Council. Their average weight was 225 g.

The injection technique was that of Belt and King (1945) as modified by Attygalle *et al.* (1956), to allow introduction of the dust suspension through a long blunt

TABLE 2

PATHOLOGICAL CHANGES PRODUCED IN RAT LUNGS BY DIAMOND AND QUARTZ DUSTS

Days of Survival	Diamond (100 mg.)		Quartz (2 mg.)		Diamond (100 mg.) + Quartz (2 mg.)		Quartz (5 mg.)		Diamond (100 mg.) + Quartz (5 mg.)	
	Mode of Death	Grade of Fibrosis	Mode of Death	Grade of Fibrosis	Mode of Death	Grade of Fibrosis	Mode of Death	Grade of Fibrosis	Mode of Death	Grade of Fibrosis
100	Died	0	Died	0	Died	1			Died	1
	,,	0							,,	1
200	Killed	0	Killed	1	Killed	1	Killed	1	Killed	1
	,,	0	,,	1	,,	1	,,	1	,,	1
300	,,	0	,,	1	,,	1	,,	2	,,	2 max.
			,,	1	,,	1	,,	2		
400	,,	0	,,	1	,,	2	,,	2	,,	2 max.
	,,	0	,,	1	,,	2	,,	2	,,	3
							,,	2		

Max. = maximal within the stated grade of fibrosis.

needle inserted through the mouth and down to the bifurcation of the trachea.

The duration of the experiments was 400 days. A few animals died, and the rest were killed at intervals (Table 2).

The histological and pathological procedures were as described by Belt and King (1945) and as detailed in the other communications from this laboratory already referred to.

The pathological results of the injections of dusts were assessed histologically, in terms of degrees of fibrosis as defined by Belt and King (1945), *i.e.*, grade 1 fibrosis, in which, with ordinary nuclear stains, the lesions appear cellular, while a loose network of reticulin is seen with silver impregnation, no collagen being demonstrable. In grade 2 fibrosis lesions are cellular with the reticulin fibres becoming thicker and arranged in a compact manner; there may or may not be collagen. In grade 3 fibrosis lesions are slightly cellular and composed mainly of collagen fibres. Two further grades are recognized, namely, grade 4 fibrosis in which the lesions are completely acellular and wholly collagenous, and grade 5 fibrosis, in which lesions are acellular, collagenous, and confluent, but these were not attained in this experiment.

Results

The diamond dust alone gave rise to no fibrosis even after 400 days. With quartz alone, 2 mg. produced a few scattered lesions of grade 1 fibrosis by 200 days, with no increase at 400 days, while 5 mg. produced a few scattered nodules of grade 2 fibrosis by 300 days, with no increase at 400 days.

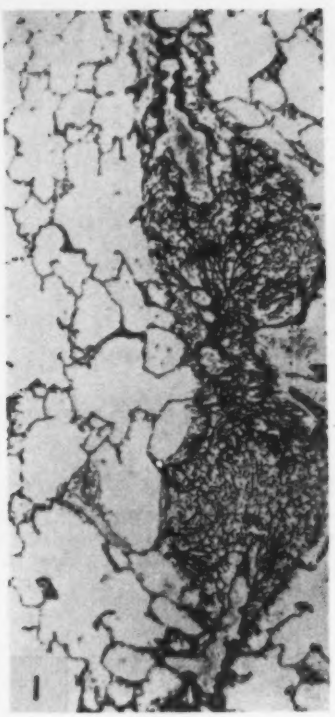
Diamond dust combined with 2% of quartz dust (100 mg. diamond + 2 mg. quartz) caused numerous lesions of grade 1 fibrosis at 200 days, which progressed to grade 2 at 400 days. With 5 % of quartz combined with diamond the lesions appeared to be more numerous, and were slightly more fibrotic, *i.e.*, grade 1 at 200 days and grade 2 maximum and grade 3 at 400 days. It seems, therefore, that the combined effect of diamond dust and varying amounts of quartz is to produce more pathological response than either of them produces alone, and that, as with coal, the effects of the combined dusts are greater than the apparent sums of each of them taken separately. Photomicrographs of representative sections of the lungs are reproduced in Figs. 1-5.

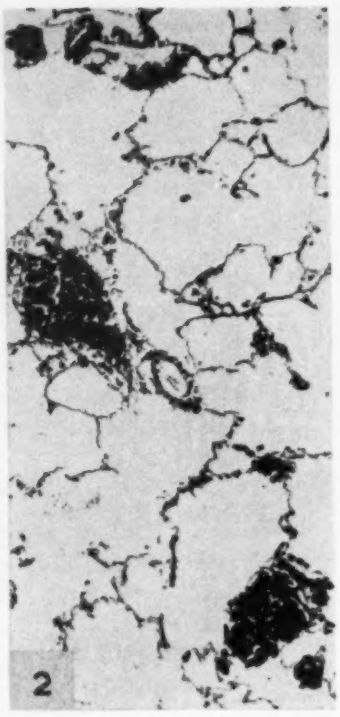
Discussion

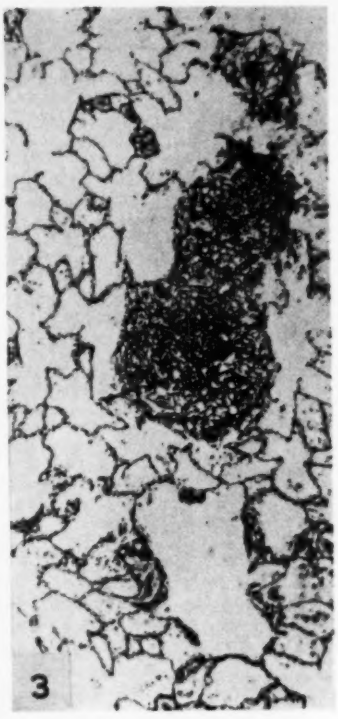
Attygalle *et al.* (1956) found that 1 mg. tridymite was almost entirely cleared from the lungs, where no fibrosis was found, but that it gave rise to grade 1 maximum fibrosis of the lymph nodes. The 2 mg. and 5 mg. of quartz used in the present experiments were not completely cleared from the lungs, and some scattered foci of fibrosis were found, particularly with the 5 mg. As in the case of coal, it appeared that with diamond dust present in large amounts in the lung there is less movement of small amounts of quartz particles to the lymph nodes than there is in the absence of the diamond dust. Nussbaum (1956) has also advanced the view that innocuous dust in large concentrations may enhance the effect of small amounts of injurious dust by retarding their elimination from the lung.

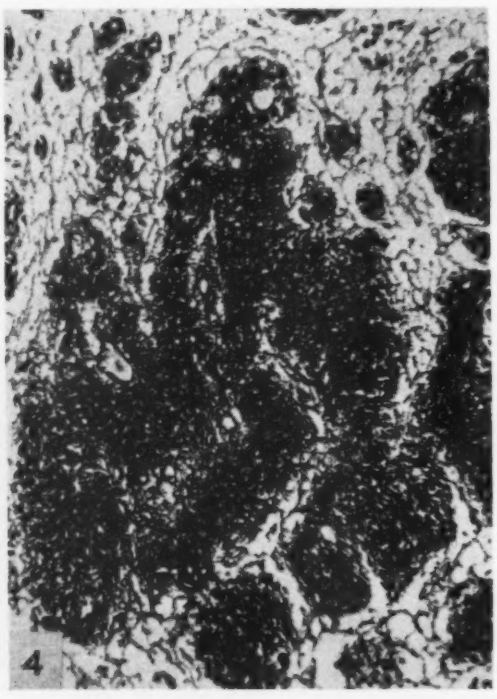
An injection of 100 mg. of dust into a rat will result in permanent retention of about 50 mg. (Nagelschmidt, Nelson, King, Attygalle, and Yoganathan, 1957). Human lungs of 200 g. dry weight are approximately 300 times heavier than rat lungs of average dry weight of 0·7 g., so that the dose applied would correspond to finding in a human lung 15 g. of total dust with 0·3 to 0·75 g. of quartz. Such amounts are found in lungs of pathological grade 2 (reticulation) in South Wales coal workers (King, Maguire, and Nagelschmidt, 1956), or in lungs which show radiological stage 1 of simple pneumoconiosis, according to unpublished data. These are comparatively early stages of disease not usually associated with any disability.

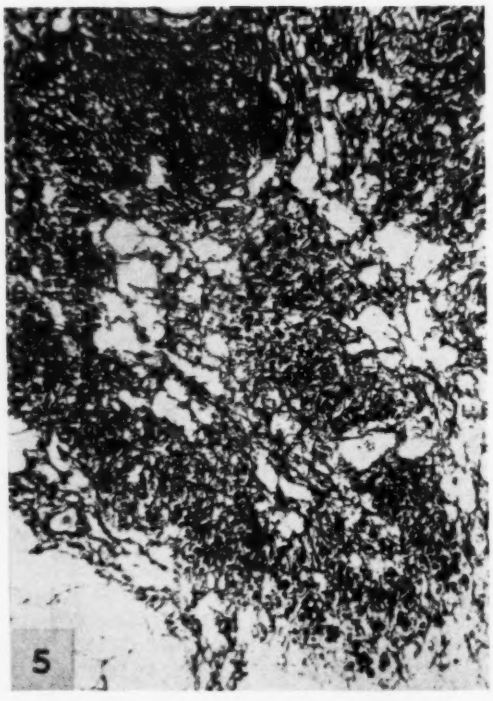
It is known that in man dusts with a proportion of quartz of the order of 20% or more cause silicosis. Coal-mine dusts contain on an average only 2 to











FIGS. 1-5.—Rat lungs 400 days after the intratracheal injection of quartz dust, diamond dust, and diamond mixed with quartz dust. Silver impregnation × 90.

FIG. 1.—Quartz dust, 2 mg., peribronchial nodules of reticulin fibres. Grade 1 fibrosis.

FIG. 2.—Diamond dust, 100 mg. Small compact foci densely packed with dust; no increase of reticulin.

FIG. 3.—Quartz dust, 5 mg. Small compact nodule composed of thick strands of reticulin and some collagen fibres. Grade 2 fibrosis.

FIG. 4.—Diamond dust, 100 mg., *plus* quartz dust, 2 mg. Compact lesions containing much dust and composed of thick reticulin and collagen fibres. Grade 2 fibrosis.

FIG. 5.—Diamond dust, 100 mg., *plus* quartz dust, 5 mg. Lesions containing much dust and composed of thick strands of reticulin and collagen fibres. Grade 2 fibrosis maximum.

4% of quartz, and the aetiological significance of quartz in such mixed dusts is not well established. The experiments described above and similar previous experiments suggest that fibrosis is slightly more advanced when 2 or 5% of quartz is injected with large doses of coal, graphite, or diamond, but it is not certain that similar results would be given by dust inhalation; further experiments to establish this point are in progress.

Summary

Diamond dust (100 mg.; 99% under 2μ) caused no fibrosis in rats' lungs in 400 days when introduced by the intratracheal injection technique. Small amounts of quartz (2 and 5 mg.; 95% under 2μ) produced only a few scattered lesions of grades 1 and 2 fibrosis. Diamond dust (100 mg.) combined with quartz (2 and 5 mg.) produced many more lesions which were somewhat more fibrosed (grade 2, and 2 maximum, and 3). The results are discussed in their possible relation to coal-miner's pneumoconiosis.

We are grateful to the Medical Research Council and to the National Coal Board for grants to defray the expenses of this investigation, and to Mr. B. S. C. Hollands for skilled technical assistance, and the Ministry of Power for permission to publish this paper.

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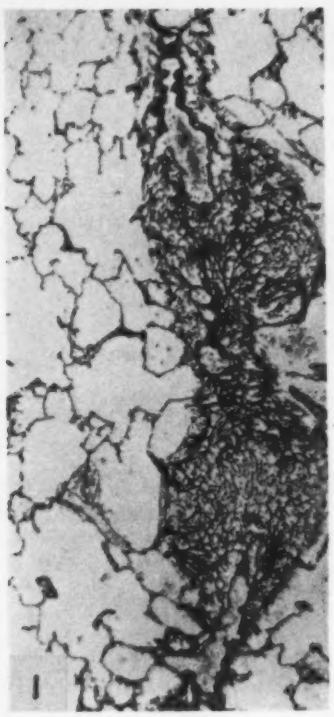

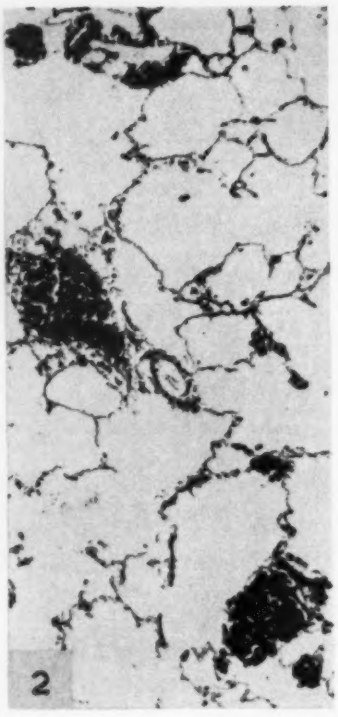

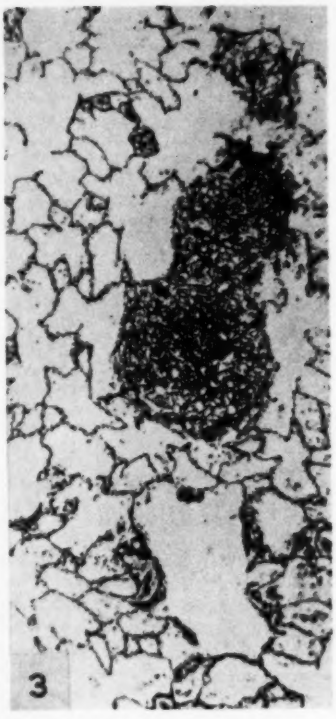

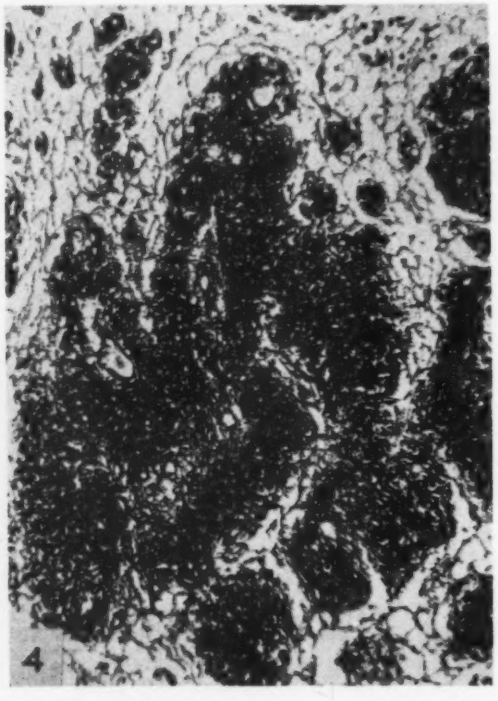

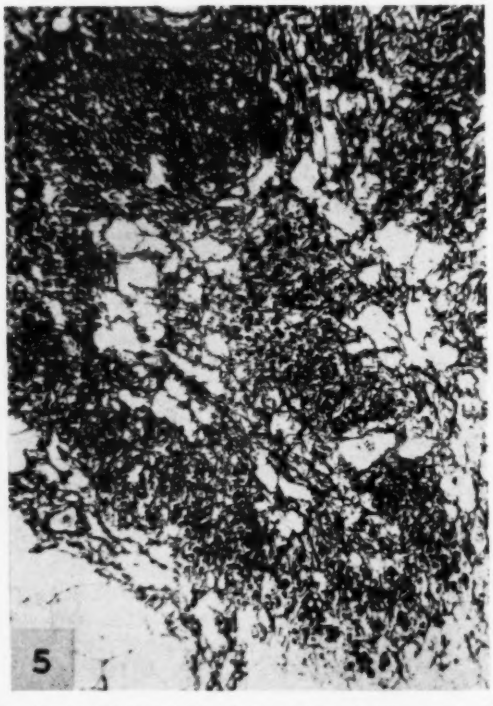

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THE PREVALENCE OF PULMONARY TUBERCULOSIS IN A NORTHERN TRANSVAAL COPPER-MINE RELATED TO THE IMPORTANCE OF PRE-EMPLOYMENT RADIOGRAPHS

BY

G. E. DALTON

From the Messina (Transvaal) Development Co., Ltd.

(RECEIVED FOR PUBLICATION OCTOBER 22, 1956)

The importance of pre-employment chest radiography in the elimination of pulmonary tuberculosis from the mines is now widely recognized. In South Wales, mining entrants have been radiographed since 1940 but in the rest of Great Britain this has only become general since nationalization of the coal industry in 1948. In the U.S.A. the practice is not yet universal but varies with the firm. In the Union of South Africa all European employees in scheduled gold-mines have had pre-employment chest radiographs for many years; but this practice did not apply to a large number of unscheduled mines (gold, copper, or asbestos) nor to African labourers. Recent legislation (1956) has made pre-employment chest radiography of both European and African employees compulsory in most mines in the country. The inclusion of African miners in this scheme is important in view of the high prevalence of pulmonary tuberculosis among them. A recent survey in the Northern Transvaal (Union Government Committee of Enquiry into Pneumoconiosis and Tuberculosis, 1955-56) revealed a prevalence of tuberculosis of 7·8 per thousand in a rural African population. Dormer in 1943 found a prevalence for the same area of 23 per thousand. In the Bechuanaland Protectorate the prevalence was estimated to be 13 per thousand (1952) and in Kenya 11 per thousand (1949). Estimates for Nyasaland and the Rhodesias, from which a large proportion of the mine's African labour is recruited, are not available, but there is no reason to suppose that the incidence of tuberculosis in these countries differs much from the figures given. The latest available estimates for the Union of South Africa are up to 5 per thousand for Europeans and between 10 and 20 per thousand for non-Europeans (Viljoen, 1957).

Description of the Copper-mine

The copper-mine at which the surveys described in this paper were carried out is situated at Messina in the Northern Transvaal, nine miles from the Limpopo River. Mining has been carried out for 50 years and there are now four shafts descending to varying depths of up to 4,000 feet. The mining consists of excavating large areas and little work is done in narrow or confined spaces. Little water is encountered underground and temperature and humidity are not unduly high. Water sprays and atomizers are the chief means of controlling dust. Results of control are good and for dustiness the mine compares very favourably with other mines in the country.

About 2,000 Africans and 250 Whites are employed underground. The Africans are recruited from various sources including the Rhodesias and Nyasaland. A proportion have previously been employed in gold or asbestos mines in the south. They are not engaged for any definite period; some work a month or two, others for 20 years or longer with periods of home leave. There is consequently a high labour turnover of about 50% of the total complement per annum. There are no other industries in the neighbourhood, the surrounding African population being engaged mostly in farm work.

The African labourers are housed in compounds where both single and married accommodation is available. Adequate rations are issued to all employees and their families on a scale laid down by Government regulation. Neither housing nor malnutrition is therefore likely to be an important factor in causing the spread of tuberculosis. The climate of Messina is sub-tropical, the summers

being hot, the winters mild, with an annual rainfall of approximately 13 inches.

The mine came within the requirements of the Union of South Africa Silicosis Act in September, 1953, and since then pre-employment chest radiography of white miners has been compulsory. Recent legislation has made it compulsory for both Europeans and Africans to have such an examination and Africans have in fact been radiographed since July, 1955. Before this time only clinical examination of the chest was carried out.

No detailed statistics are available of the prevalence of tuberculosis among the African employees before the present survey. Between 1938 and 1952, however, 156 patients suffering from pulmonary tuberculosis were admitted to the African hospitals serving the mine. The average total African labour force for this period was 3,673 giving a prevalence of tuberculosis of 4·2 per thousand per annum; 94 cases occurred in underground workers who averaged 1,855 over the same period. This gives an approximate rate in underground workers of 5·1 per thousand per annum. These rates can be considered to give only a very uncertain indication of the true rates as only the advanced cases were likely to be discovered and the actual prevalence of tuberculosis for 1938-52 must have been considerably higher than 5·1 per thousand.

Sixty-five per cent. of cases occurred in labourers who had had less than three years' service in the mine.

First Mass Radiography Survey

In September, 1953, a survey of all African underground workers was carried out by a unit of the Silicosis Medical Bureau. One thousand, nine hundred and forty-seven workers were radiographed and of these 156 were recalled for full-sized films, but 17 failed to attend either because they refused or because they had left the mine. The results are given in Table 1.

TABLE 1

CLASSIFICATION OF RADIOGRAPHS OF 156 WORKERS RECALLED FOR LARGE FILMS RESULTING FROM FIRST MASS RADIOGRAPHY SURVEY

	Large Film	Miniature Film	Total	Rate per 1,000 of Population Radiographed
Normal	33	—	33	—
Inactive tuberculosis	6	10	16	8·2
Clinically significant tuberculosis	46	3	49	25·2
Silicosis	23	2	25	12·8
Silico-tuberculosis	31	2	33	16·9
Total ..	139	17	156	

Sputum examinations were carried out on 93 of the 106 men with abnormal large films. In six of the cases of clinically significant tuberculosis and in eight of the cases of silico-tuberculosis, acid-fast bacilli were found, giving a prevalence of infectious tuberculosis of 7·2 per thousand of the population radiographed.

As a number of the radiographed employees left the mine, only 55 out of the 100 cases in which significant radiological abnormality had been detected were submitted to the Silicosis Bureau for certification. Of these 47 (24·1 per thousand total radiographed) were certified (Table 2).

TABLE 2

CERTIFICATION OF TUBERCULOSIS OR SILICOSIS BY SILICOSIS BUREAU AFTER 1953 SURVEY

Population radiographed	1,947
No. certified as suffering from silicosis	15 (7·7 per 1,000)
No. certified as suffering from tuberculosis	16 (8·2 per 1,000)
No. certified as suffering from tuberculosis and silicosis	16 (8·2 per 1,000)
Total certified	47 (24·1 per 1,000)

But for the lapses there would probably have been a considerably higher certification rate. All those certified as suffering from silicosis and/or tuberculosis were suspended from further mining activities, as required under the Silicosis Act, 1953. Thus a number of infectious and potentially infectious cases of tuberculosis were removed from mining employment. A few were allowed to continue in employment pending further examination.

Since July, 1955, all African recruits for both surface and underground mining have had a pre-employment chest radiograph. Between July, 1955, and July, 1956, 2,432 recruits were examined and 10 (4·1 per 1,000) were rejected on account of clinically significant tuberculosis. No record is available of those rejected on account of silicosis.

Second Mass Radiography Survey

All African underground workers were again radiographed in June, 1956. The population radiographed was 1,936 and of these 63 were recalled for large films but two failed to attend. The results are shown in Table 3.

TABLE 3

CLASSIFICATION OF RADIOGRAPHS OF 63 WORKERS RECALLED FOR LARGE FILMS RESULTING FROM SECOND MASS RADIOGRAPHY SURVEY

	Large Film	Miniature Film	Total	Rate per 1,000 Population Radiographed
Normal	24	—	24	—
Inactive tuberculosis	4	—	4	2·1
Clinically significant tuberculosis	6	1	7	3·6
Silicosis	25	1	26	13·4
Silico-tuberculosis	2	—	2	1·0
Total ..	61	2	63	

Table 3 reveals a gratifying fall, compared with 1953, in the prevalence of tuberculosis but shows no change in the prevalence of uncomplicated silicosis. One of the cases of clinically significant tuberculosis was found to have a positive sputum. This case, together with one of the remaining five in this group, was subsequently certified as suffering from tuberculosis by the Silicosis Medical Bureau. Of the other four patients in this group, one was certified as suffering from silico-tuberculosis, two returned to employment, and one deserted.

One of the cases of silico-tuberculosis had a positive sputum and was certified as suffering from tuberculosis only. The other case deserted after the taking of the large film.

In the second survey, therefore, only two cases were found to have acid-fast bacilli in the sputum, giving a prevalence of infectious tuberculosis of one per 1,000 of the population radiographed. No infectious tuberculosis was found in those with silicosis only.

Comment

The reduction in the prevalence of tuberculosis in the mine between 1953 and 1956 (Table 4) is striking and may be attributed to two factors. As a result of the first survey, Africans found to be suffering from tuberculosis were suspended from work in the mines and this must certainly have been the main cause for the reduction. In addition, the introduction of pre-employment chest radiography prevented the recruitment of cases of active tuberculosis which, if the figures for 1955-56 are considered representative, was taking place at the rate of about four cases per thousand new entrants.

TABLE 4

REDUCTION IN TUBERCULOSIS RATES AMONG UNDERGROUND AFRICAN COPPER-MINERS BETWEEN 1953 AND 1956

	Rate per 1,000 Radiographed (September, 1953)	Rate per 1,000 Radiographed (June, 1956)
Clinically significant tuberculosis	25·2	3·6
Infectious tuberculosis	7·2	1·0
Silico-tuberculosis	16·9	1·0

Summary

The results of two mass radiography surveys of the African underground employees in a copper-mine carried out in 1953 and 1956 are described. At the time of the first survey the prevalence of clinically significant tuberculosis was 25·2 per 1,000 and of silico-tuberculosis 16·9 per 1,000. The corresponding prevalence rates at the second survey were 3·6 per 1,000 and 1 per 1,000. This reduction is considered to be partly due to the removal of cases of active tuberculosis found as a result of the first survey and partly to the inauguration of routine pre-employment chest radiography which is estimated to prevent the recruitment of about four cases of tuberculosis per thousand new entrants.

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SOME PRELIMINARY THOUGHTS ON THE HUMAN DEMANDS OF AUTOMATION*

BY

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It has often been suggested that some of the lines of work developed during and since the war in relation to Service problems can be directly applied to automation: studies for example, of responses to rapid series of signals, of situations requiring vigilance, and of displays and display-control relationships—in short, the stuff of which the psychological aspect of ergonomics has in large measure hitherto consisted. It would seem, however, that these studies are directly relevant in only a very limited way. Industrial conditions from this point of view are more leisurely and predictable than those in the Services, so that rapid response is seldom needed except in rare circumstances, as, for example, in sudden emergencies. Vigilance situations are of types which have in the past shown relatively little problem in that they do not involve the observation of short-duration signals occurring at random, but of watching developing trends in a situation where signals for action do not quickly come and go but gradually increase in magnitude until they are dealt with. Men can get used to almost any display conditions and display-control relationships that are not so obviously wrong that they have already been considered from an *ad hoc* point of view by management and engineers. There is still a great deal of research to be done on these matters for industry has not managed to solve all its own problems in this area, or indeed to realize them, but solving them would not remove many of the main human problems of operating and maintaining automatic machinery.

The Service work is significant for our present purpose, however, to the extent that it implies, when taken in conjunction with more fundamental studies, certain principles of operation of the human organism which may produce different but, nevertheless, important results in industrial work. To put it another way, if we wish to transfer knowledge gained from research done in a Service context to industry, and vice versa, it is necessary to go, not directly but via consideration of the human mechanisms involved.

We shall here consider a number of factors which appear to be important from this point of view and have implications for the design of automation equipment.

Limited Human "Channel Capacity"

Many researches have now shown well nigh conclusively that the human organism behaves as a single channel of limited information transfer capacity. It can receive input continuously over many channels and give a continuous output over various effectors, but between these there appears to be a single channel dealing with only one transfer from input to output at one time. It is in this channel that limitations on speed of work commonly occur, although in certain circumstances they can arise in other parts of the chain of mechanisms, for example, in the fact that the eyes can only see one small part of a field in foveal vision at a time, or that we have only two hands with which to carry out manual operations.

All forms of automation reduce the number of actual manipulative movements the operator is required to make. The load upon this single channel which results from the need for fine control of movements is therefore also reduced. In so far, however, as there is an increased need for watching and

*This paper derives from a survey by Miss H. M. Clay, Dr. E. R. F. W. Crossman and the writer, which is being undertaken for the Department of Scientific and Industrial Research and sponsored by the D.S.I.R. and M.R.C. Joint Committee on Individual Efficiency in Industry in an attempt to assess in terms of human skill the demands of work normally included under the heading of automation. The word "skill" is used here in a somewhat broader sense than commonly in industry, to cover not only recognized trade and craft work but any human performance which can show an "expert" quality. The paper represents an attempt at orientation following a study of the literature and a number of factory and other visits, both viewed against a background of general experimental psychology. It was read at a Symposium held by the Ergonomics Research Society at Bristol on April 8-11, 1957.

listening to what plant or machinery is doing, automation may actually increase the total informational load upon the operator. For instance, on a line of transfer machines the operator who is loading may have a relatively simple manipulative task but will, nevertheless, be very fully employed in observing that the machine is working properly. The load upon him will not so much consist in looking at the actual control panel, which, in examples seen, does not appear difficult to deal with, as in listening to how the machine is functioning—information probably too subtle to be represented on a panel without unduly elaborate sensing devices.

The limitation upon human channel capacity will have its most serious effects where work is paced by some external agency. Contrary to some statements which have been made, all process control operations are paced in the sense that signals for action are liable to arise at times which are not entirely of the operator's own choosing and responses have to be made within time limits. The pacing varies greatly in severity, however, from conditions where processes are remotely but entirely humanly controlled, in which the pacing may be far more exacting than that of a conveyor line, to conditions where the operator's task is almost entirely to monitor a self-regulating set of machinery, taking action only in an emergency. Except in an emergency this latter kind of work is virtually unpaced. Two points need to be made about such conditions. First, however slow the pacing is normally, if signals for action can occur at random and demand attention within very short time limits, there is inevitably a danger that the operator will upon rare occasions be overloaded and that in consequence necessary action will be omitted and an accident result. The events in any actual process are of course far from random; but it seems worth while consciously to build into such a system means of ensuring that the most sudden and unfortunate emergency possible could never present the operator with a situation in which he would not be able to take the necessary action in time.

The second point is that factors in some way related to speed of work have been known for a long time to produce very different subjective effects in the human operator. We can perhaps distinguish four: (1) If the rate is very fast, the operator shows signs of " strain ". (2) Rates somewhat slower than this seem to fall within an optimum zone in which strain is absent and the operator's interest is engaged and well maintained. (3) A rate still slower appears to lead to feelings of boredom and to an unwillingness to do the task. (4) An even slower rate seems to restore tolerable conditions because most of the operator's time is spent doing something other than his main task, for example, reading a book or talking to his neighbours. The precise nature of the speed factor involved has not been determined. It cannot be the number of responses required, nor can it be amount of sensory stimulation. A more likely factor on the basis of present knowledge is " information " in the information theory sense of the term. Objectively, too fast a rate gives rise to tenseness in the subject, hurrying, inaccuracy, and possibly omission of some of the required actions. The changes of behaviour and efficiency which accompany boredom are less well known and more research is needed.

It is a reasonable inference from studies of repetition workers that individual differences exist in just what rate produces what effects: in particular, the optimum becomes lower with diminishing intelligence. The best way of dealing with a boring job of process control might therefore appear to be to employ unintelligent people. This would, however, often mean that the operators were not intelligent enough to take such action as might be necessary from time to time, especially in an emergency. If, therefore, optimum conditions are to be maintained, one of three courses appears to be required: either (*a*) some strictly unnecessary work has to be added to the task—in some plants operators have periodically to record readings on the dials they are watching, although the data are of no use except as a check that the dials are being inspected occasionally; or (*b*) such operations need to be deliberately designed for evenness in the amount of intelligence they require at different periods of a working spell; or (*c*) two people must be employed—one to watch and one to be called in if intelligent action is thought likely to be required.

Before leaving considerations of speed, two further points need briefly to be mentioned. First, work relating time required to make choices to the number of potential alternatives has made it clear that the larger the number of possible signals that have to be watched for, the longer it is likely to take to identify any one when it arrives. Thus a simple increase in the size and complexity of the machine or plant that an operator has to supervise may make its minding more difficult. Secondly, the time taken to deal with signals is increased if they have to be discriminated against a confusing background of other signals or " noise " in the information theory sense: thus the presentation of too much data may be as deleterious to good performance as the presentation of too little. We may here note that one of the uses of computers which has been recommended is for the production of information for management in a digested form, enabling them to see easily facts which if not in such reduced form would involve

the inspection of an impossibly large array of figures.

Rules of Action

The principle that lies behind the results of studies of display-control relationships is that for any job it is necessary to learn and retain a set of " translations " between what we see and what we do. With direct hand actions or hand tools these translations are reasonably straightforward and are learned in the course of manipulating toys at an early age. All forms of mechanization and automation tend to replace these simple relationships with others which are not learned so early and have some element of " arbitrariness " about them. Work on relationships of this kind has shown that some are more in line with expectations than others, presumably because they bear some recognizable similarity to those met with previously, but that almost any set can be learnt and used moderately well provided it is consistent within one machine and from one machine to another used by the same operator. Confusion is likely to arise, however, if inconsistent relationships are required in the same job or between different jobs done by the same man. The confusion may possibly tend to disappear with long experience, but inconsistencies seem likely to lengthen training periods and to remain as a source of confusion on rare occasions for a long time after they have ceased to be troublesome from day to day.

The requirement of consistency and the need it implies for rigid standardization is worth stressing, especially at the present time, because there is an unusual opportunity for manufacturers to adopt and users to demand that certain conventions be rigidly adhered to in the new equipment likely to be installed in the next few years. To achieve standardization will not be without its problems because there are still a number of questions in need of solution before complete standards can be definitely laid down.

The same principle supports the view that standard unit construction, especially of electronic apparatus, would make for easier maintenance and enable lower grade or less trained operatives to do the work. Such construction might for this reason be worth while, even at the cost of using a considerably larger number of components. The principle indicates perhaps with even more force the desirability of anticipatory maintenance according to rule instead of maintenance by repair following breakdown.

Conceptualization of the Process

Probably the most important aspect of the principle we have been discussing is, however, that display-control relationships seem to provide what can be regarded as, in a very literal sense of the word, elementary examples of conceptualization of the process being controlled. There is little doubt that one of the most important abilities of the operator on a complex machine is, and will to an increasing extent become, that of having some " picture " or " model " in his mind of the machine and of its work. The picture or model need not be as complete as that which an engineer would have and need not even be accurate, provided it enables the operator to do two things: first, to give meaning to the sight and sounds of the machinery he is controlling, and secondly to monitor by observation of results what is going on in parts of the machine or of the plant he cannot actually see.

Just what is involved in such conceptualization has never been fully formulated, but it appears to involve two processes, about each of which something is already known and further close study would be worth while.

It seems to require the coordination into a " scheme " or " frame of reference " of pieces of data culled at different times in the course of experience. We all use schemes of this general kind in order, for example, to maintain spatial orientation and find our way about. It is well known that individuals differ in their ability to build and maintain such schemes and that circumstances may hinder or facilitate their formation. Some practical steps towards making conceptualization easier have already been taken in the diagrammatic layout of instrument panels, but clearly more needs to be known, especially with regard to training men to monitor machines which do not readily lend themselves to such display methods. In any case, it must be emphasized that good instrument layout can deal with only a part of the whole problem, which may perhaps be epitomized by asking the question, " How do we acquire the ability to ' sense ' whether our car is running well or not and how can we train someone else to do the same ? "

The second aspect of conceptualization which is important in this context is the ability to manipulate data in the abstract—to imagine events which are not seen or which, as in the case of electronic apparatus, are unobservable. Such ability enters largely into so-called intelligence tests, and it is perhaps understandable that Vernon (1947) in his studies of the intelligence test scores of British naval personnel during the war found that electrical artificers attained scores higher on average than those of any other rating. They were a little higher than those of R.N. executive officers and Fleet Air Arm observers and pilots and were exceeded only by those of R.N. engineering officers. There are not many people with mental ability at this level and

it is important therefore to consider ways in which the working of a machine can be represented to the operator in as concrete a manner as possible. At the same time, however, we should recognize that long experience with the same machine—implying stability of employment—is likely to enable a man to achieve an understanding of this one particular machine which he would be unable to attain on a more general basis.

A few other points may be more briefly mentioned.

Anticipatory Action and Prediction

When a man forms part of a control loop, the time relations are important between the taking of action and its becoming effective. If the time is long the man must either predict the effects of his actions so that he makes a " ballistic " adjustment to his controls which will produce the correct results after the system has settled down, or he will tend to oscillate in a series of more or less violent over-corrections. If using velocity controls he may also be faced with the need to remember action taken at one moment with a view to taking cancelling action at a later time, often, if the process is slow, after other actions have been taken during the interval. The load upon his short-term retention in such circumstances can be severe, with consequent danger of adjustments being forgotten.

Where possible, it would be worth while to build into the apparatus means of avoiding the need for the operator to predict and remember in this way, for example, by giving indication immediately of what the eventual effect of his action will be when the system has settled down, or of storing data for him by devices such as cursors on scales which can be set to indicate required readings so that discrepancies can easily be noted. To do this might often require a degree of definition of the task greater than had yet been undertaken, especially when many variables have to be controlled simultaneously. Engineers and management seem often to have despaired of the task of formulating processes sufficiently to enable predictors or automatic control to be used. Instead, a carefully selected operator is employed who manipulates controls to produce a more or less satisfactory end-product by some means akin to an art, which he obviously does not fully understand and certainly cannot adequately formulate in words. The definition of such skills—and they are skills in a very real sense of the word—is not at present possible, although a few tentative suggestions can be made. Perhaps the most significant of these is that as the number of variables is increased, the difficulty of the task seems, for a variety of reasons, to increase disproportionately. The control of only one or two variables in a complex task might therefore be expected to reduce the difficulty for the operator much more than would be predicted from a study of a task involving these one or two variables in a simpler context.

Changes in Nature of Skill Resulting from Automation

Skilled action in the broad sense of the term is of many different kinds; but probably the most difficult components of manipulative tasks, as practised by semi-skilled operatives on work such as light assembly and which enter into skilled craft operations, are the making of precisely graded ballistic movements. It is characteristic of automatic processes that fine motor control is no longer required and in this respect they seem to make the operator's task much easier. Fine motor actions appear to need continual training if a high level of performance is to be maintained: the " rustiness " of a tennis player at the beginning of the season or of a concert musician out of practice, has its industrial counterparts.

There remains a requirement to perform actions in the correct order, but with many automatic machines, especially, for example, with tape-fed machines, the order of actions is worked out once for all at leisure and does not have to be carried in the mind of the operator the whole time. For him, the simpler routine of loading the machine is sufficient, and this can be made common to what would before have been tasks involving many different routines.

Automation may also tend to replace fine subjective judgments, such as of the colour of molten metal, which may take years to acquire and, like fine graded movements, require continual practice to maintain.

Viewing these changes together it appears that automation tends to conserve skill in the sense that it reduces the need for traditional components of skill to be used repetitively, and leaves men to use their unique human capacity for dealing with the complex and the variable in primary construction, in emergencies, and to some extent in maintenance. Even in this last we may doubtless look forward to a kind of " meta-automation " where such items as tool grinding will be carried out automatically.

The Operator's Need for Adequate Information

The fact that the operator of automatic plant is often removed from direct contact with the process he is controlling emphasizes the need to consider thoroughly what information he needs to be supplied with in order to do his work not only accurately but with confidence. Broadly speaking he must have unambiguous indications of what is

happening and of the effects of his actions, and must also have data which will enable him to be sure that his apparatus is at all times working properly—absence of significant events in the process should not be signalled merely by absence of any indication.

The indications should be such that they are clear and do not require any elaborate process of inference or piecing together of data from several sources. Ideally every fundamentally distinct event should be separately signalled. What constitutes a " fundamental distinction " in this sense is often intuitively obvious although it is not precisely definable. To do so in general terms a great deal of research would be needed, the contributions of which would have considerable theoretical as well as practical significance.

Re-training of Middle-aged Operatives

One of the most important, although probably temporary, problems introduced by automation is due to the fact that men and women re-deployed as a result of changes of process and work method will probably be middle-aged and in consequence have some difficulties in acquiring new knowledge. We cannot enter into this matter fully here, but the evidence is that the essential difficulty experienced by middle-aged people when learning new tasks lies not so much in learning and retention as in the actual process of taking training, so that suitable methods of training for people in middle age seems likely very substantially to reduce their problems. The devising of new methods of training for this purpose seems to be an urgent need.

Responsibility

Of the human qualities having rarity value which are commonly suggested as important for operatives in an automatic plant, the most frequently cited is a " sense of responsibility ". This is, however, a vague term which needs further definition before it can guide the selection of men or the design of jobs. In the present context it seems commonly to cover three requirements. (*a*) The first is reliability in the sense that behaviour should be predictable and not show " random " variations due either to insufficient attention to the job or to taking action other than what is prescribed, whether by error or in an attempt to improve upon established routine. Ensuring reliable operators is probably, in the present state of knowledge, a matter of selection, probably by means of trial on the job. (*b*) The second requirement is that whatever has to be done shall be done with sufficient accuracy as quickly as possible. This requirement might in fact be made very much less pressing by systematic and thorough application of engineering psychology principles to the simplification of the job. (*c*) A requirement of a somewhat different kind is a willingness to recognize one's place in a hierarchy without the corresponding willingness to " pass the buck ". Both this and the preceding quality raise problems of motivation, incentive, and will to work. Doubtless recognized factors such as knowledge of results, understanding of the part played by the operation in the final product, payment methods, and so on, will have some application still under automatic conditions. We may suspect, however, that it will be necessary sooner or later to regard these aspects of responsibility as attitudinal matters, or, to use an older word, " moral " matters and to consider their implications for the status of the operator. They appear to be characteristic of what one might call a vocational or professional approach to work and to raise the possibility that operators should be given salaried positions.

Satisfaction with Work

Discussions of the effects of automation frequently raise the intangible, subjective and therefore somewhat suspect, concept of work satisfaction. It must be recognized that degree of work satisfaction is one of several end-products of the factors already discussed and should not be considered apart from them. Other factors also contribute, however, and must be taken into account when making an overall survey of the human demands of automation. The suggestion is often made that the monotonous conditions and relative isolation of workpeople from one another in an automatic factory may cause dissatisfaction. On the other hand, attention to the points raised earlier seems likely at least to minimize dissatisfaction if not indeed to make work more satisfying than it had been before. Two other subjective factors seem also to be worth mention and research study. First, the control of powerful and highly productive machinery seems likely to have an inherently satisfying effect, possibly because of the high ratio of result to effort obtained by its use. As against this, large and powerful plant may be dangerous in the sense that failure to operate it correctly may lead to serious results and factors not under the operator's control may produce a danger of accidents. The risk may be very small but there are suggestions that when hazards of this kind are recognized to exist the effect over many years may lead to an unwillingness to continue with the job, or alternatively to signs of strain. Secondly, many people seem to derive their chief satisfaction from the creation of something unique, regardless of the effort involved. Automatic plant appears at first sight to diminish this second type of satisfaction. It is likely, however, that many of the new jobs will have something of this quality. For example, those

designing programmes for computers seem to derive satisfaction from the fact that a new programme, once made, is in a sense a unique and enduring product, capable of continued use without having to be created again. We may perhaps add that the automatic production of necessities and "essential luxuries" may well bring greater opportunities for the artist and craftsman in certain areas of production not covered by automation, and bring their work into increasing demand.

The indications of the various points outlined in this paper are by no means mutually compatible, so that the machine and process designer will often have to balance one inconsistent requirement against another. The result—that each case needs careful individual consideration—does not mean, however, that general principles cannot be formulated. It does mean some rather exacting analytical thinking on the part of those who seek to understand the psychological problems of automation.

Summary

An attempt is made to outline some of the factors in human skilled performance which seem, from the standpoint of experimental psychology, likely to be of importance in work with automation equipment.

Automation appears to reduce the need among operators for actual manipulative skill but to place increased emphasis upon a number of more intellectual capacities. These demands are discussed in terms of (1) the limited "information channel capacity" of the human organism with the suggestion that both over- and underloading of this capacity are to be avoided; (2) the need for consistency in the relationships between display and control; and (3) the coordination of data from many sources and arriving at different times, and the conceptualization of the task which appears to be necessary for adequate performance.

Briefer discussion is included of the problem of what constitutes adequate information in displays, of the most suitable routines for repair work, of the urgent need to devise methods of re-training middle-aged operatives who have to be redeployed, of what is meant by "responsibility" on the part of operatives, and of the likelihood that automation will result in gains as well as losses in work satisfaction.

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A CLINICAL STUDY OF BEAT KNEE

BY

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Beat knee is defined as " a subcutaneous cellulitis or acute bursitis arising at or about the knee " in the First Schedule to the National Insurance (Industrial Injuries) (Prescribed Diseases) Regulations, 1948. The cases considered in this paper all fell within this definition.

Our continued observation of many miners with beat knee who attended medical treatment centres at mines suggested that there were well-defined clinical patterns not described in the accepted broad classifications of previous writers (Collis and Llewellyn, 1924; Watkins, 1951; Atkins and Marks, 1952; Watkins and Hunt, 1954).

With the object of confirming this suggestion, a systematic study was undertaken for 18 months in 1954-55 of cases of beat knee occurring in a large group of mines, mainly in the North Derbyshire coal fields, employing 17,899 men underground. A total of 899 cases of beat knee occurred in this period, and were included in the study; there was no selection. It was also felt that a detailed clinical study might throw more light on the relationship of beat knee to the working environment of the miner. The clinical findings in each case were recorded separately, with relevant personal and environmental data. The state registered nurses in charge of medical treatment centres were given intensive tuition in the recognition of the different clinical types of beat knee, and issued with a set of photographs illustrating each main type. Any case in which the classification was doubtful was examined and classified by a medical officer. After checking for completion, the records were transferred to Powers-Samas punched cards for statistical analysis.

The Knee in Coal-miners

It is frequently impossible for the coal-miner to work standing, and in some places he must work lying down. He is often compelled to work in the kneeling position during the whole of his shift of seven hours because of the low height of the coalface. His kneeling posture varies according to the task in which he is engaged, and according to personal preference; but kneel he must, and while kneeling, he transmits his body weight through his knees on to the floor of the coalface, which is carpeted with coal fragments. Changes in the kneeling posture distribute the body weight through different angles, and pressure may therefore be exerted at different points in the knee area.

In the past the emphasis in causation of beat knee has been placed mainly on abrasions of the skin caused by sharp coal particles, with subsequent infection of the underlying tissues. The effects of continued and repeated local pressures have received less attention.

Clinical Classification

Pain is the predominant symptom in all cases. It brings the miner for treatment and sends him off work. The chief clinical features of beat knee are a bursitis and a cellulitis in the region of the knee, existing separately or together. Our belief that these were separate clinical types of beat knee was confirmed, and it was found that all cases could be included in three main clinical groups. Further division of these enabled 11 clinical types of beat knee to be identified. The main groups and their seven subdivisions are shown in Table 1, which also gives the number of cases in each category.

TABLE 1

CLINICAL TYPES OF BEAT KNEE

Main Clinical Type	Subdivision		No. of Cases		% Total Cases
Simple bursitis		Suprapatellar	41		
		Prepatellar	389	632	70·3
		Infrapatellar	202		
Cellulitis		Diffuse	5		
		Local	98	103	11·5
Combined Bursitis and cellulitis	Diffuse	Suprapatellar	3		
		Prepatellar	35		
		Infrapatellar	27	164	18·2
	Local	Suprapatellar	7		
		Prepatellar	46		
		Infrapatellar	46		
	Total ..		899		100·0

Simple Bursitis.—The bursae were clearly defined when they were distended with fluid and the overlying skin showed no sign of inflammation. Three anatomical types could be clearly differentiated on clinical examination and together formed 70·3% of the total beat knee cases.

(1) The suprapatellar bursa extends upwards from the upper margin of the patella deep to the quadriceps.

(2) The prepatellar bursa lies mainly in front of the patella and its ligament. When it is distended with fluid this bursa can usually be distinguished without difficulty from the infrapatellar bursa which lies in front of the tibial tubercle and the tendon insertion. In the majority of cases the clinical differentiation can be made by the simple test of placing the finger immediately across and below the line of the lower border of the patella, thus defining the position of the distended bursa.

(3) There is also a deep infrapatellar bursa, small and of little importance, lying between the patellar tendon and the upper part of the tibial tubercle. When enlarged, it protrudes along the lateral margins of the patellar tendon. This is grouped clinically with infrapatellar bursitis as it is rarely seen alone.

Cellulitis.—Diffuse cellulitis spreading over the front of the knee was unmistakable. Local cellulitis differed in extent only, and often merged imperceptibly into a boil or an infected abrasion. This group represented only 11·5% of the beat knee cases.

Combined Bursitis and Cellulitis.—Cellulitis was present in a local or diffuse form together with enlargement of the adjacent bursa in 18·2% of the total cases.

Recurrence

During the 18-month period of our study 80 men had between them 92 recurrences of beat knee. Eleven men had two recurrences, and one had three. Of the 80 men who experienced recurrences, 59 had simple bursitis in their first attack. Eleven of the recurrences in these 59 were due to cellulitis. The remaining 21 had cellulitis in their first attack, and 15 of the recurrences in this group were also due to cellulitis.

It is interesting to note that of the 59 recurrences in the simple bursitis cases, 48 recurred at the same site. This may have been due to the fact that a miner, who is compelled to kneel at his work, establishes by experience and possibly advice from his colleagues a kneeling posture which, once he has accustomed himself to it, remains with him as an established working posture.

Relation to Environment

The incidence of beat knee in our series varied widely between collieries, the lowest being 13·25 per 1,000 men underground, and the highest 105·4 per 1,000 men underground. This wide variation suggested that environmental differences might be important.

Occupation.—When the cases were classified by occupation it was found that 96% occurred in coal-face workers who represented only 54% of the total underground labour force (Table 2). Coal-getters comprised only 25% of the total underground labour force, but contributed 57·1% of the cases.

TABLE 2

OCCUPATIONAL ANALYSIS OF BEAT KNEE CASES

Occupation	No. of Cases	% Total Cases
Coal-face workers:		
Coal-getters	513	57·1
Drillers	25	2·8
Shotfirers and deputies	39	4·3
Conveyor shifters	25	2·8
Coal cutter men	24	2·7
Rippers and packers	174	19·3
Other faceworkers	66	7·3
Other underground workers	33	3·7
Total	899	100·0

Rippers and packers together comprised about the same number of faceworkers as coal-getters, yet they produced only 19·3% of the cases compared with 57·1% among coal-getters. This is presumably due to the fact that rippers and packers do not kneel as long as the coal-getters.

Coal-face Height.—The incidence of beat knee at the pits included in our study varied according to the height of the seam at the coal-face. We could find no inter-relationship between the occupation of the miner, his age, and the seam thickness.

TABLE 3

PERCENTAGE OF CASES BY CLINICAL CONDITION AND COAL-FACE HEIGHT IN COAL-FACE WORKERS ONLY

Seam Height	No. of Beat Knee Cases	% Cases in Each Clinical Type				
		Simple Bursitis			Cellulitis	Combined Cellulitis and Bursitis
		Suprapatellar	Prepatellar	Infrapatellar		
Less than 4 ft.	662	5	41	23	9	22
4 ft. and over	204	3	50	19	19	9
Total	866	4	44	22	11	19

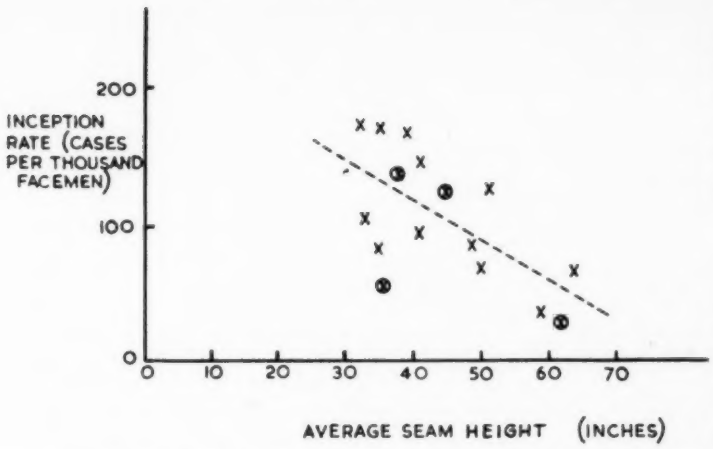

FIG. 1.—Inception rates of beat knee by seam height in faceworkers only in 18 months at 16 collieries.
Collieries not using predominantly the most common method of mining are circled.

Fig. 1 and Table 3 indicate that the incidence of beat knee is related to seam height. They show the increased incidence of cases of beat knee in the thinner seams. Seventy-six per cent. of all cases in the series reviewed occurred in men working in heights less than 4 ft., while only 63% of the total man shifts were worked in these heights. The findings emphasize the importance of coal-face heights as an environmental factor in the causation of beat knee. The reason is the difficulty which the coal-face worker in low seams has in adopting, for working comfort, any other posture than kneeling.

Protective Equipment

The varieties of knee pads worn by faceworkers were of four main types: (*a*) Rubber-lined cup, (*b*) felt-lined pads, (*c*) bursa pads, (*d*) trouser pads. Eight hundred and twenty-one faceworkers in the cases under review during the period wore knee pads; 45 faceworkers did not. Rubber-lined cups and felt-lined pads were those most commonly used; only a few men used trouser pads. No association was found between clinical condition and the type of pad worn (Table 4).

It is evident that these types of knee pads do not prevent beat knee in coal-miners who must work in a kneeling position.

TABLE 4
CLINICAL CONDITION AND TYPE OF KNEE PAD WORN BY FACEWORKERS ONLY

Clinical Condition	No Pads Used	Bursa Pads	Rubber-lined Cups	Felt-lined Pads	Trouser Pads	Total
	Cases	Cases	Cases	Cases	Cases	Cases
Simple bursitis	32	145	233	195	3	608
Cellulitis	8	18	31	39	—	96
Combined bursitis and cellulitis	5	37	67	53	—	162
Total..	45	200	331	287	3	866

Age

Table 5 shows that younger men are more susceptible to beat knee than older men. Two reasons might account for this: one, that the knee, through constant use, adjusts itself to withstanding the pressures of coal-face work in a limited height; the second, that getting coal is the most physically arduous task as well as the occupation most susceptible to beat knee, and this is usually performed by men in the younger age groups. Fig. 2 gives the beat knee inception rates by age for coal-face workers in three different colliery areas for the period of the survey.

TABLE 5
AGE-GROUP ANALYSIS

Age Group	No. of Underground Workers on Books	No. of Cases of Beat Knee	No. of Cases per 1,000 Men on Books	No. of Shifts Lost	Average No. of Shifts Lost per Case
All Cases:					
Under 21	1,785	126	70·6	594	4·7
21–25	1,634	141	86·3	785	5·6
26–30	2,050	182	88·8	562	3·1
31–40	4,268	218	51·1	1,341	6·2
41–50	4,054	150	37·0	1,016	6·8
51–60	3,073	70	22·8	719	10·3
61–64	762	11	14·4	101	9·2
65 and over	273	1	3·7	—	—
Total for all ages	17,899	899	50·2	5,118	5·7
Coal-face Workers Only:					
Under 21	506	123	243	594	4·8
21–25	1,159	137	118	745	5·4
26–30	1,583	177	112	533	3·0
31–40	3,171	215	68	1,322	6·2
41–50	2,551	143	56	987	6·9
51–60	1,337	61	46	622	10·2
61–64	193	10	52	92	9·2
65 and over	23	—	—	—	—
Total for all ages	10,523	866	82	4,895	5·7

Period of Incapacity

There are many factors which influence the length of time a miner suffering from beat knee may be off work; as in other disabling states, social and personal factors may play their part. Our experience during this review has shown that the presence at a mine of facilities for early diagnosis and adequate treat-

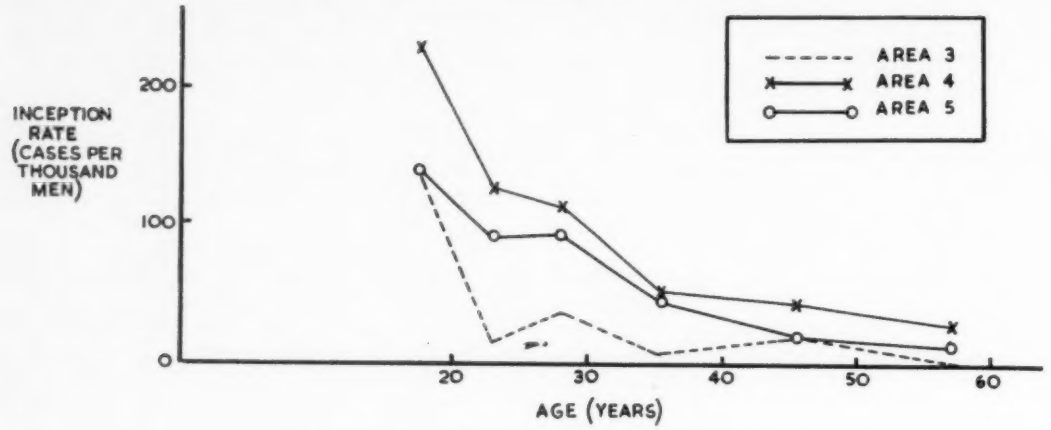

FIG. 2.—Inception rates of beat knee by age in coal-face workers only.

ment considerably reduces the number of shifts lost per case (Table 6).

TABLE 6
PERIOD OF INCAPACITY IN RELATION TO TREATMENT CATEGORY

Treatment Category	No. of Cases	% Total Cases	No. of Shifts Lost	Average No. of Shifts Lost per Case
A. Reported to and treated at colliery medical treatment centre	557	62·0	1,174	2·1
B. Reported to own doctor but treated at colliery medical treatment centre	143	15·9	1,247	8·7
C. Reported to medical treatment centre but treated elsewhere	95	10·6	1,141	12·0
D. Reported to and treated elsewhere	104	11·6	1,556	15·0
Total	899	100·0	5,118	5·7

The clinical type of beat knee influences the time lost. For example, a swollen infected bursa often takes longer to resolve than a localized cellulitis limited to the skin and subcutaneous tissues.

The age of the miner suffering from beat knee is of significance. Our results show (Table 5) that in all the cases of beat knee studied, and in those among faceworkers only, the time loss sustained in shifts was greater at the higher ages. One explanation for this may be that for the older person the disability offers the opportunity for a needed rest, not previously acknowledged. We have sometimes found that when persons suffering from beat knee were absent for a long period, the causative factor was social in origin, such as " illness in the home ".

The treatment of beat knee is not described here, but we believe that the form of treatment is an important element in determining the amount of time lost. A definite régime was followed in the majority of cases treated in medical treatment centres at collieries (Fernandez, 1958). The value of this régime was proved by the fact that while the average shift loss for all cases was 5·7 shifts, for those treated entirely at medical treatment centres at collieries it was only 2·1 shifts (Tables 5 and 6).

Discussion

Collis and Llewellyn (1924) stressed the importance of the infective element in beat knee; Atkins and Marks (1952) believed systemic infection to be an important factor in the causation of beat knee. In our series, however, 70·3% of the cases showed no evidence of infection. This may be due to the fact that the vast majority of men (94·4%) wore knee pads, and had bathing facilities at 15 of the 17 collieries reviewed. Thus, the majority of men had facilities for keeping the skin of the knees clean.

Collis and Llewellyn also reported the bursa " over the shin bone " to be most commonly affected, while we have found that the prepatellar bursa was the commonest, 44%, against only 22% of infrapatellar bursa cases among coal-face workers (Table 3).

Our results show that the coal-face worker most frequently affected is the coal-getter, this group having three times as many cases as the next group, rippers and packers. The coal-filler moves far less on the coal-face than men in the other occupations, and this probably explains why he is more susceptible; his knees are subject to more continuous pressure than those of other coal-face workers.

When a miner kneels, the floor presses against the tibial tuberosity, yet the commonest affected bursa is the prepatellar, an area he does not kneel on; this

may be due to redistribution of pressure due to knee pads.

We have seen many cases of enlarged bursa aspirated in the early phases, and in the majority of cases altered blood has been drawn off. We believe that the simple, painful bursitis of sudden onset is due to haemorrhage into the bursa, and that this occasionally becomes infected. Where there is no enlargement of the bursa but only infected skin, it is our view that the condition originates in abrasions of the skin which subsequently become infected. Painless enlargement of the bursae is sometimes seen. Such enlargements often persist for long periods, and we agree with Collis and Llewellyn's view that they are harmless. Chronic, painless bursal enlargements probably arise from persistence of an unresolved acute condition.

Summary

Eight hundred and ninety-nine cases of beat knee occurring in coal-miners at a large group of mines are reviewed. Definite clinical patterns were seen and 11 distinct clinical types are described. Simple bursitis was far more common than the infective condition. The clinical signs were determined by the relative extent of the bursitis element and the infective element. Pain was the dominant symptom. Beat knee was commonest among young coal-face workers, especially the coal-getter.

Four types of knee pads were worn by coal-face workers at the collieries under review; they were ineffective in the prevention of beat knee.

An average of 5·7 shifts was lost per case; in those cases reporting at, and receiving treatment at, medical treatment centres, only 2·1 shifts were lost per case. In cases not reporting or treated at medical treatment centres, 15 shifts were lost per case. The recurrence rate of beat knee cases during the 18 months of our study was 10%.

Coal-face height was the most important environmental factor in causation.

We are indebted to the East Midlands Division of the National Coal Board for the facilities granted for this investigation. In particular we wish to thank Mr. R. W. Phillips, Divisional Statistical Officer, Mr. W. Cree, and Miss D. H. Jackson for their help with the records, and the state registered nurses and members of the production staff at the mines concerned.

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THE PARADOX IN THE TREATMENT OF BEAT KNEE

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The definition of beat knee used throughout this paper is given in the First Schedule to the National Insurance (Industrial Injuries) (Prescribed Diseases) Regulations, 1948. Beat knee is defined there as " a subcutaneous cellulitis or acute bursitis arising at or about the knee ". Coal-miners who kneel at their work sometimes acquire this painful condition, which usually necessitates sick leave for two to six weeks.

Pithead baths to clean the skin of the knee, knee pads to lessen the trauma of continued kneeling, and early first-aid treatment to prevent skin infection, have all been suggested (Collis and Llewellyn, 1924) as preventive measures. None of these measures is at present effective in preventing beat knee.

In a coal-mining area of 18 collieries, approximately 18,000 men were employed in 1952, of whom 7,950 worked on their knees in an average coal-face height of 3 ft. 3 in. Almost all the kneeling miners wore knee pads, and over 80% used pithead baths at the end of their shift. The services of seven State registered nurses, each in charge of a medical centre, were available to 59% of the kneeling group; for the remainder of this group treatment was available at medical units staffed by first-aid men. During 1952, a total of 590 men received injury benefit for beat knee; none had received injury benefit for this condition during the previous 12 months.

Because kneeling causes beat knee, most medical practitioners believe that miners should not return to work until the knee has fully recovered. The treatment usually given by the family doctor consists of rest, the application of local hyperaemic agents such as glycerine and ichthyol, kaolin poultices, and iodine ointment, supplemented with intramuscular penicillin when there is infection. Strapping the knee has been recommended (Collis and Llewellyn, 1924) for reducing the swelling, but this is difficult to maintain at work and also weakens the thigh muscles.

It is the pain of beat knee which causes miners to cease work and the intensity of the pain is less when the patient is standing upright than when kneeling. One method of preventing men from going on sick leave for this condition is therefore to provide tasks which do not entail kneeling. However, the fall in earnings of men temporarily transferred from the coal-face to other work, and the difficulties of organization so created, cause such arrangements to be unpopular with managements and men. An investigation was therefore undertaken of the treatment of beat knee while the patient was still engaged at his usual work.

A large mine dressing was placed in front of the knee and held in position by the knee pad. When worn inside the trousers (trousers are worn at work by almost all the men in the area) the dressing prevented abrasion of the skin by pieces of coal and dirt. When the affected knee was flexed, the knee pad pressed on to the knee, acting as a pressure bandage and kneeling was thereby rendered much more comfortable. Continued kneeling at work was not permitted when enlarged, painful inguinal glands or a raised temperature were present.

Treatment Régime

At one pit in 1952, the following treatment régime was adopted:—

Each man suffering from beat knee was encouraged to continue kneeling and a large mine dressing was provided for him to wear at work. Daily, at the medical unit, the skin of the knee was rubbed with surgical spirit for five minutes to clean and harden the skin. At the same time, the miner was taught to exercise the quadriceps muscle by voluntary contractions with the knee in the right-angled position. Each man was instructed to carry out this exercise for five minutes every hour when awake, and especially at work. Those men who practised the quadriceps exercises regularly, and the majority did so, stated that the knee became almost painless within two days. Scrubbing the knee with soap and water after bathing was essential

in order to remove the considerable amount of dirt which embedded itself in the folds of the skin of the knee. Ordinary bathing was useless for adequately cleansing the skin. Many men at first found difficulty in contracting and relaxing the quadriceps muscle in the right-angled position. These men were taught to contract and relax the quadriceps, first with the knee extended, then semi-flexed, and finally with the knee at a right angle.

The results of this treatment régime were satisfactory, and free from complications. All medical units and medical treatment centres in the area therefore adopted the régime during 1953 for cases voluntarily reporting with beat knee. During this period cases in which definite infection was present were not treated in this way.

In 1953, as compared with 1952 (Table 1), there were more men working in narrower seams, yet 191 fewer men were off work for four days or more on account of beat knee. This reduction was considered to be due to the treatment régime, which was voluntary, and well received by the men.

TABLE 1

MINING CONDITIONS AND STATISTICS OF SICKNESS ABSENCE IN COAL-FACE WORKERS DUE TO ALL CAUSES AND BEAT KNEE, 1952-56

	1952	1953	1954	1955	1956
Average no. of coal-face men employed	7,950	8,220	8,350	8,350	8,340
Shifts not worked, accounted for by a medical certificate for any reason, expressed as a percentage of total possible shifts	6·44	8·00	7·74	7·62	7·82
No. of miners receiving injury benefit for beat knee, *i.e.*, off work for 4 days or more	590	399	304	277	268
No. of cases of beat knee receiving injury benefit per 100,000 manshifts worked	13·3	9·1	6·8	6·4	6·3
Average coal-face height (ft. in.)	3 3	3 3¼	3 2¼	3 2	3 2¼
Percentage of coal-face men provided with bathing facilities	81	84	86	92	97
Percentage of coal-face men provided with medical centre facilities	59	67	68	75	89

Various methods of increasing the blood supply to the skin over the knee were then investigated. Trials showed that actinotherapy appeared to be more effective in producing hyperaemia than the local applications listed above. Counter-irritants may be dangerous; one old collier's remedy was to pour hot water on the knee until blisters appeared. It was found that ultra-violet light applied for five to 10 minutes produced the same degree of hyperaemia as 20 minutes of infra-red radiation. Apart from the saving of time by using ultra-violet light, it was also thought that the bactericidal action of the latter might reduce the infection of skin abrasions.

The radiation generated from the "hanovia" duotherapy lamps, which were standard equipment at the medical centres, consisted of the components (*Actinotherapy Technique*) given in Table 2.

TABLE 2

COMPONENTS OF RADIATION EMITTED BY TREATMENT LAMPS

Type of Radiation	Wave Length (A°.U.)	Energy-quantum (unit 10^{12} ergs)	Percentage of Each Type of Radiation
Ultra-violet			
(*a*) Producing erythema	1,850–3,130	9·8–6·3	17·5
(*b*) Abiotic	3,130–4,000	6·3–4·9	10·7
Visible	4,000–8,000	4·9–2·5	26·5
Infra-red	8 000–30μ	2·5–0·22	45·3

The initial exposure was for five minutes with the knee placed 2 ft. from the arc tube. The affected knee was given a daily treatment, and the time was increased daily by one minute until 10 minutes' exposure had been given. The distance between the arc and the knee was then reduced to 18 in., with an exposure time of five minutes. The latter was then increased by one minute daily. This radiation therapy was given in addition to the treatment régime described above to all men reporting to medical centres on account of beat knee in 1954 and in subsequent years.

The vast majority of men during this period worked on longwall faces, where the coal was machine cut and then manually shovelled on to conveyor belts. There was no evidence to show that the yearly increase in the number of men working on the coal-face, where the coal was machine mined, had any influence on the incidence of beat knee at the pits investigated.

Table 1 shows that mining conditions and the number of men at risk remained approximately the same in 1954-55-56 as in 1952-53. However, the number of men who ceased work for four days or more on account of beat knee fell from 590 in 1952 to 268 in 1956, a reduction to less than half.

During part of 1956 records were kept of 375 men treated for beat knee at the medical centres. Two hundred and sixty-seven of these were treated by the régime described and continued to kneel at their normal occupations, 29 attempted kneeling but found it too painful, 79 did not kneel, and 65 were off work.

Of the 29 men under treatment who found kneeling at work too painful, 10 stopped work on the first day of kneeling, 16 on the second, and one each on the third, seventh, and fourteenth days. Their occupations are listed in Table 3. Infection was present in eight of these cases, and in 34 men who continued to kneel at work. Seventeen of the 29

men who stopped kneeling had acute prepatellar bursitis (two infected), six had acute infrapatellar bursitis (two infected), two had acute suprapatellar bursitis, and four had septic skin conditions. Table 3 shows that men at all coal-face occupations were treated while at work.

TABLE 3

NUMBERS OF MINERS IN DIFFERENT OCCUPATIONS UNDER TREATMENT FOR BEAT KNEE CONTINUING AND STOPPING KNEELING AT WORK

Occupation	No. of Men Continuing Kneeling at Work	No. of Men Stopping Kneeling at Work under Treatment	No. of Men Given the Treatment Régime while Off Work	Total
Fillers	186	21	44	251
Packers	19	1	8	28
Underground fitters	13	0	2	15
Rippers	11	2	5	18
Shotfirers	9	1	1	11
Erectors	9	1	0	10
Cutter men	8	1	1	10
Deputies	7	2	2	11
Borers	5	0	0	5
Other underground workers	8	0	2	10
Surface workers	6	0	0	6
Total ..	281	29	65	375

Many more coal-fillers than men in other occupations were treated for beat knee (Table 3). The coal-filler kneels in a restricted height, shovelling approximately 10 tons of coal on to a conveyor belt during the shift of seven and a half hours. The time taken for beat knee in coal-fillers to return to normal (in comparison with the unaffected knee) while continuing to work is compared in Tables 4 and 6 with that for coal-face workers and haulage and surface men treated while off work. Table 4 shows that the recovery time was generally shorter in men who continued to kneel than in those who did not kneel, and that only after 10 treatments were the percentage recoveries approximately the same in the two groups. Apart from kneeling, both groups were given the same treatment, and the interval between successive treatments was never more than three days.

TABLE 4

PERCENTAGES OF BEAT KNEE CASES RECOVERING AFTER A GIVEN NUMBER OF TREATMENTS

Occupation	Percentage Recovered in						Total No. of Cases Treated
	2 Treatments	4 Treatments	6 Treatments	8 Treatments	10 Treatments	12 Treatments	
Coal-fillers kneeling	18	49	75	83	89	96	186
Coal-fillers not kneeling	5	23	57	73	89	93	44
Coal-face men kneeling	5	24	60	73	90	94	63
Coal-face men not kneeling plus haulage and surface men	4	25	56	70	86	92	79

The initial degree of swelling, pain, or infection did not appear to be related to the recovery time. Some infected bursae returned to normal in a week, while a small, relatively painless enlarged bursa sometimes took two weeks to recover.

One argument that is sometimes advanced against kneeling at work is the danger of recurrence. Table 5 gives particulars of the nine cases which recurred within 28 days of the initial onset of beat knee. Of the 267 cases in 1956 in men who continued to kneel at work, six (2.3%) had a recurrence against three (3·8%) of the 79 men who did not kneel. Four of the six men who knelt continued to kneel while the recurrence was treated and two of the three who did not kneel during their first attack of beat knee did so during the recurrence. The evidence suggests, therefore, that there is no greater risk of recurrence in beat knee while kneeling at work under the described treatment régime than in cases treated without kneeling. One factor which influences coal-face men to continue kneeling at work is the soreness experienced when they return to work after being away for longer than a fortnight.

TABLE 5

PARTICULARS OF CASES OF RECURRENCE OF BEAT KNEE

Occupation	Type of Bursitis	No. of Days from Initial Onset to Recurrence	Type of Recurrent Bursitis and Action Taken
Filler, kneeling	Prepatellar	3	Prepatellar, stopped kneeling
Filler, kneeling	Prepatellar	13	Prepatellar, continued kneeling
Filler, kneeling	Septic skin only	13	Septic prepatellar, stopped kneeling
Borer, kneeling	Prepatellar	14	Prepatellar, continued kneeling
Filler, kneeling	Prepatellar	15	Prepatellar, continued kneeling
Borer, kneeling	Prepatellar	28	Prepatellar, continued kneeling
Filler, stopped kneeling	Infrapatellar	3	Infrapatellar, continued kneeling
Filler, stopped kneeling	Prepatellar	9	Prepatellar, stopped kneeling
Filler, stopped kneeling	Prepatellar	26	Prepatellar, continued kneeling

Types of Beat Knee

Table 6 shows the number of treatments required before the knee returned to normal for different types of beat knee occurring in coal-fillers and other workers kneeling and off work.

Coal-fillers with infrapatellar bursitis who continued to kneel at work required fewer treatments for the knee to return to normal than those with prepatellar bursitis, the latter having a tendency to chronicity. One reason for this may be the pressure bandage effect of the knee pad and the mine dress-

TABLE 6

TYPE OF BEAT KNEE, OCCUPATION, AND WORK STATUS RELATED TO NUMBER OF TREATMENTS REQUIRED BEFORE RECOVERY

Type of Beat Knee, Occupation, and Work Status	No. of Treatments																			Total of Beat Knee Cases
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	24	
Prepatellar bursitis; filler; at work	9	8	16	18	11	13	3	3	4	5	4	4	2	1	1	2	1	—	—	—	105
Prepatellar bursitis; filler; off work	—	—	3	3	3	4	3	2	—	2	—	—	—	—	—	—	—	1	1	—	22
Infrapatellar bursitis; filler; at work	3	7	6	8	9	7	2	3	—	1	—	—	—	—	—	—	—	—	—	—	46
Infrapatellar bursitis; filler; off work	—	1	1	—	3	—	1	—	—	2	2	—	—	—	—	—	—	—	1	—	11
Suprapatellar bursitis; filler; at work	1	2	2	1	1	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	9
Suprapatellar bursitis; filler; off work	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Infected prepatellar bursitis; filler at work	—	—	—	2	1	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	6
Infected prepatellar bursitis; filler off work	—	1	1	—	2	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	6
Infected infrapatellar bursitis; filler at work	—	—	1	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Infected infrapatellar bursitis; filler; off work	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1
Septic skin; filler; at work	—	4	3	—	4	—	—	1	1	—	2	—	—	—	1	—	—	—	—	—	16
Septic skin; filler; off work	—	—	—	—	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	3
Total fillers at work ..	13	21	28	29	28	21	6	8	6	6	7	5	2	1	2	2	1	—	—	—	186
Total fillers off work ..	—	2	5	3	10	5	5	2	1	6	2	—	—	—	—	—	—	1	2	—	44
Other coal-face workers at work	5	16	16	12	9	7	3	2	—	4	3	1	1	—	—	2	—	—	—	—	81
Other coal-face workers off work	—	1	2	2	5	3	1	—	1	2	—	1	—	1	—	—	—	—	—	—	19
Haulage and surface workers at work	—	—	3	2	1	—	1	2	3	—	—	2	—	—	—	—	—	—	—	—	14
Haulage and surface workers off work	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	2

ing, although the pressure of kneeling is greater on the infrapatellar bursa than on the prepatellar bursa. In most individuals, the suprapatellar bursa communicates with the knee joint (Frazer and Robbins, 1937), but the 10 enlarged, unaffected suprapatellar bursae treated resolved as quickly as the prepatellar bursitis cases.

Infection of the skin or bursa did not affect the prognosis; of 36 such cases, the majority returned to work within seven days.

Chronic Bursitis

Four cases of enlarged bursae became painless, but the swelling did not resolve under the treatment régime. These cases are not listed in the series reviewed. All were prepatellar in position and they represented 1% of the total cases treated. These patients came to no harm, although they continued kneeling. No evidence was found to support the view (Collis and Llewellyn, 1924) that the risk of infection in such patients is greater than in the normal knee in men working on the coal-face.

Complications of Beat Knee

No complications occurred in the present series of cases treated.

A rare interesting complication, of which I have seen four cases, is the development of a massive oedema from the bursa to the ankle, occurring in less than 24 hours from the onset. None of the cases treated in the present series had this condition. In all four cases the dorsalis pedis and posterior tibial pulsation was normal, and no thrombus could be felt in the popliteal artery. One common factor which might have accounted for these cases was constriction behind the knee in a patient with a large pre-existing prepatellar bursa. Constriction of the veins around the knee appeared to be the main cause.

Discussion

The fact that 375 men were treated at the collieries during part of 1956 suggests that the régime was popular. Although many men lived some distance from work, almost a third of those who were off work for four days or more took advantage of the treatment régime, with the consent of their own doctor.

At 14 pits during the first 10 months of 1956, the number of men with beat knee observed was 481, but less than half of these required sick leave for more than three days. The existing design of knee

pads was considered to be ineffective for the prevention of beat knee. Ninety-seven per cent of the men had bathing facilities, and whereas the baths did not prevent the occurrence of beat knee, they may well have reduced the number of cases with skin infection, which we found in only 7% of the total number of cases.

Summary

Kneeling is generally prohibited when cases of beat knee are under treatment. A treatment régime is described in which kneeling at work is continued. The results were satisfactory, and 90% of men found kneeling possible while under treatment.

The number of cases of beat knee on sick leave for four days or more for 1955 and 1956 was half that in 1952 when the régime described was not used. Mining conditions and the number of men at risk were approximately the same in the two periods.

The treatment régime consisted of scrubbing the knee, quadriceps exercises in a right-angled position, use of a large mine dressing to kneel on, and a high dosage of ultra-violet light to the front of the knee. The treatment was effective in cases complicated by infection.

Paradoxically, although kneeling causes beat knee, yet by acting as a pressure bandage, kneeling also caused the recovery time to be shorter under the régime described. In men who continued to kneel at work, infrapatellar bursitis resolved more rapidly than prepatellar bursitis. This was considered to be due to the fact that the knee pad and mine dressing were more efficient as a pressure bandage in infrapatellar bursitis cases. Kneeling was not permitted when patients with beat knee had a raised temperature or large, painful inguinal glands.

The recurrence rate of cases treated while engaged in normal kneeling work was no higher than in men who stopped kneeling.

In four cases of massive swelling of the leg associated with beat knee, it was thought that this condition was associated with the interference with the venous return due to constriction at the knee.

The existing design of knee pads was considered ineffective in preventing beat knee.

The views expressed in this article are my own, and not necessarily those of the National Coal Board. I am very grateful to the Divisional Medical Officer of the East Midlands Division, Dr. J. T. Watkins, for much helpful advice, also to Dr. T. A. Hunt, whose photographs of beat knee helped in differentiating the clinical types. Special thanks are due to Dr. G. Farquharson and Dr. R. A. Rickett.

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THE SEDIMENTATION RATE AND FRAGILITY OF HUMAN ERYTHROCYTES *IN VITRO* AFTER EXPOSURE TO LEAD CHLORIDE

BY

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One important contributory factor in producing anaemia in lead poisoning in human subjects is undoubtedly the inhibition of the biosynthesis of haem in erythroid bone marrow cells (Eriksen, 1955). To what extent a haemolytic action of lead participates has been the subject of much experimental study.

McFadzean and Davis (1949) demonstrated more abundant stippled cells in the bone marrow of lead-poisoned guinea-pigs than in the peripheral circulation, such cells being rapidly and preferentially taken up by the spleen. The interpretation of the data was that punctate basophilic erythrocytes were abnormal both in haemoglobin content and physical structure as a consequence of damage by lead before the corpuscles were released from the haemopoietic site.

The peripheral action of lead has not been evaluated with certainty. Aub, Fairhall, Minot, and Reznikoff (1926) made extensive studies *in vitro*, mainly on washed red blood cells in phosphate-free Ringer solutions. The addition of small quantities of lead chloride caused increased mechanical fragility of the corpuscles which, however, became more resistant to hypotonic haemolysis. An increased mechanical fragility of the circulating corpuscles through contact with plasma lead was regarded as the essential feature of the anaemia of lead poisoning. Indirect evidence which supported this view has been reported more recently, namely, raised urobilinogen excretion in lead-poisoned guinea-pigs (Baikie, 1954) and coproporphyrinuria I in severely poisoned workmen (Kench, Lane, and Varley, 1952). The data in a recent investigation (Holeček and Pěničková, 1957) are unfortunately qualitative only.

Aub and his colleagues postulated that blood lead was distributed between plasma inorganic phosphate and phosphate groups on the red blood corpuscular surface, now known to be largely dominated by such groups (Furchgott and Ponder, 1941). Lead in whole blood caused much less damage to the erythrocytes than in phosphate-free Ringer suspensions owing to the protection afforded by the plasma inorganic phosphate. Small quantities of lead added to whole blood remain in the plasma as colloidal lead phosphate, but with larger quantities relatively more lead would become bound to the erythrocytes. Changes in fragility were ascribed to the release of hydrochloric acid in the corpuscular surface layers by interaction of lead salt with inorganic phosphate groups. Certain aspects of this hypothesis have been discounted. Bischoff, Maxwell, Evans, and Nuzum (1928) observed that lead salts of weak acids, *e.g.*, lead glycerophosphate, were equally productive of similar changes in the red blood cell although no mineral acid was released. Bambach, Kehoe, and Logan (1942) and Mortensen and Kellogg (1944) described a rapid removal of lead by the red cells even at low blood levels. Clarkson and Kench (1958) from kinetic studies of interaction of lead with human erythrocytes *in vitro*, have envisaged a process involving coagulation and flocculation of a peptized lead phosphate sol on the cellular membrane. No competitive inhibition of uptake of lead was observed with any of a number of potential competitors tested, including other metal ions, namely, Cu^{2+}, Hg^{2+}, $(uO_2)^{2+}$, and Tl^{4+}. Chelating agents such as EDTA removed lead attached to erythrocytes only slowly *in vitro*, indicating that the metal was present in a practically unionized state.

The present investigation was undertaken to re-examine the behaviour of human erythrocytes following exposure to lead *in vitro*, in the light of

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the kinetic data and especially from the viewpoint of a modifying influence of inorganic phosphate.

Experimental

Materials.—Blood from healthy young men was collected from the antecubital vein into a 500 ml. lead-free bottle containing a 0·9% sodium chloride solution of 1 g. glucose and anticoagulant (heparin or an ammonium potassium oxalate mixture 3 mg. per 100 ml. blood). The blood was examined immediately after collection or stored at 4° C. and used within 48 hours.

The NaCl solutions used in this work were rendered lead free by passage through a column of sulphonated ion exchange resin, " Zeo-carb " 225 in the sodium cycle. Solutions in the Krebs Ringer bicarbonate mixture (Umbreit, Burris, and Stauffer, 1945) were deleaded in a similar way with the ion exchange column prepared in the appropriate cycle.

The apparatus was of " pyrex " glassware, which was cleaned with boiling nitric acid and then thoroughly washed with doubly distilled water. Where " pyrex " was not procurable, soda glass was coated with silicone " repelcote " (2% solution of a methyl chlorosilane in carbon tetrachloride, Hopkin and Williams Ltd.) and cleaned with nitric acid.

Methods

Erythrocyte Sedimentation Rate.—Two millilitres from well below the top of a column of packed red blood cells obtained by centrifuging whole heparinized blood were suspended in 2·5 ml. oxalated plasma and various quantities of lead chloride in the range 0 to 50 μg. lead were added. The mixture was allowed to equilibrate during 20 minutes at 20° C. Samples were removed for measurement of the sedimentation rate in Westergren tubes enclosed in a well-insulated glass tank maintained at 20 ± 0·1° C.

A similar procedure was followed for equivalent suspensions of red blood cells in 0·16 M. NaCl and in Krebs Ringer bicarbonate solution. Results are presented in Figs. 1 to 3.

Hypotonic Haemolysis Curves.—Lead chloride solution, 0·1 ml., was added to whole oxalated blood in a concentration equivalent to 11 μg. lead per ml. packed red blood cells, computed from the packed red cell volume as measured in Wintrobe tubes. The suspension was allowed to equilibrate during 30 minutes at 37° C. Afterwards a sample was removed and added to plasma, also maintained at 37° C., to give a final red blood cell suspension of 5% by volume. Of this suspension, 0·42 ml. was added to 3·6 ml. of hypotonic sodium chloride solution, the concentration of which was that required to bring the final volume (4·02 ml.) to the desired tonicity. The hypotonic saline suspensions were incubated in a water-bath at 37° C. for 30 min. The tubes were then centrifuged and the supernatant removed so as to measure the haemoglobin concentration in a " unicam" spectrophotometer S.P. 500 at 540 mμ. The 100% lysis control tube was that containing 0·4 ml. 5% red cells added to 3·6 ml. doubly distilled water, and the degree of haemolysis in the other hypotonic saline solutions was expressed as directly proportional to the haemoglobin concentration in the supernatant solutions.

Observations were repeated on the specimen of blood allowed to stand in contact with lead for a further 24 hours at 37° C. Whole blood to which no lead was added was employed as a control. A 50% by volume suspension of thrice-washed corpuscles in 0·16 M. NaCl was also studied as for whole blood. Results are presented in Figs. 4 to 6.

Results

The sedimentation curves show that whereas lead increases the erythrocyte sedimentation rate in saline (Fig. 1) the opposite is true in Krebs Ringer bicarbonate solution and in oxalated plasma (Figs 2 and 3). Differences may also be remarked between saline and plasma when considering hypotonic haemolysis. A definite resistance to haemolysis was observed when red blood cells in saline were exposed to lead for 30 min. (Fig. 4) or for 24 hours (Fig. 5), but no such effect could be detected when the metal was added to whole blood (Fig. 6).

Discussion

Our observations on sedimentation rate and fragility of erythrocytes exposed to lead are in agreement in many respects with those of Aub and his colleagues (1926). Little damage was inflicted on the cells provided excess phosphate was present, either as in whole blood or in Krebs Ringer solution.

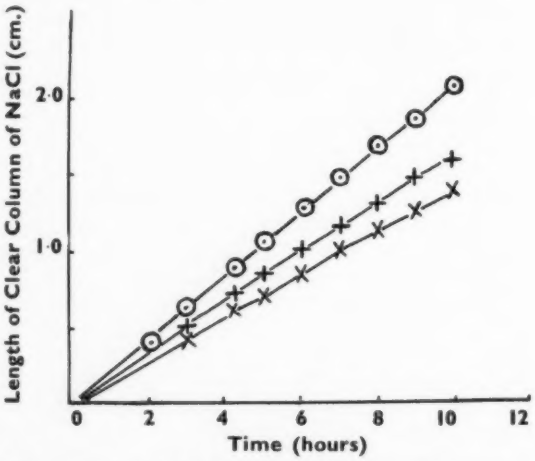


FIG. 1.—The sedimentation rate of red blood cells in saline suspension at 20° C. after exposure for 20 min. to various concentrations of lead chloride. A control curve for a saline suspension not exposed to lead is included. The suspension contained the equivalent of 2·5 ml. packed R.B.C. per 3 ml. saline.

× ——— × control curve
\+ ——— + R.B.C. exposed to lead equivalent to 5 μg. per ml. packed R.B.C.
⊙ ——— ⊙ R.B.C. exposed to lead equivalent to 50 μg. per ml. packed R.B.C.

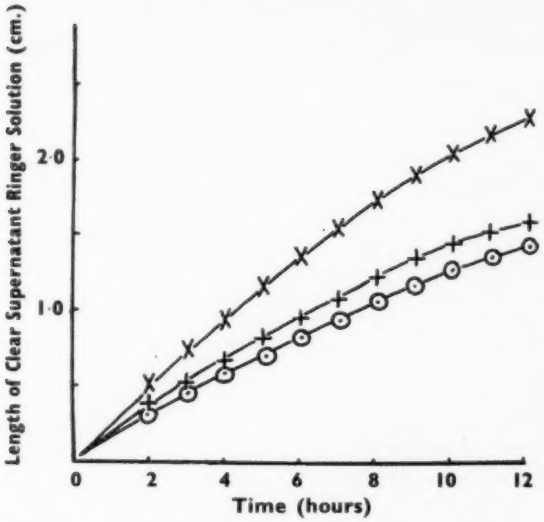


FIG. 2.—The sedimentation rate of red blood cells suspended in Krebs Ringer bicarbonate solution at 20° C. after exposure for 20 min. to various concentrations of lead chloride. A control curve for a similar suspension not exposed to lead is included. The suspension contained the equivalent of 2·5 ml. packed red cells per 3 ml. Krebs Ringer bicarbonate solution.

X ——— X control curve
\+ ——— + R.B.C. exposed to lead equivalent to 10 μg. per ml packed R.B.C.
⊙ ——— ⊙ R.B.C. exposed to lead equivalent to 50 μg. per ml. packed R.B.C.

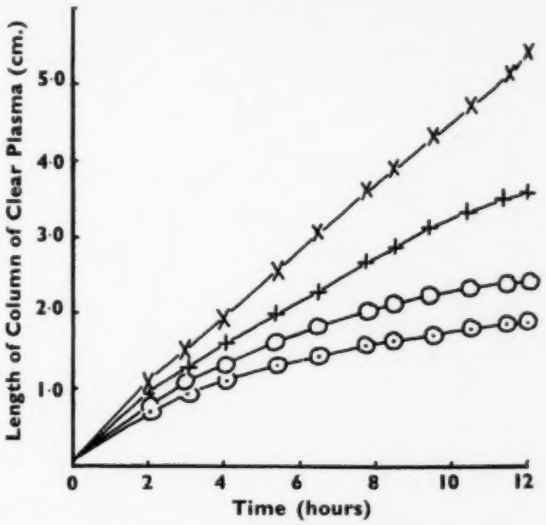


FIG. 3.—The sedimentation rate of red blood cells in whole oxalated blood at 20° C. after exposure for 20 min. to various concentrations of lead chloride. A control curve of whole blood not exposed to lead chloride is included. The whole blood used in the experiment contained the equivalent of 2·5 ml. packed red cells per 3 ml. plasma.

X ——— X control curve
\+ ——— + blood exposed to lead equivalent to 5 μg. per ml. R.B.C.
O ——— O blood exposed to lead equivalent to 20 μg. per ml. R.B.C.
⊙ ——— ⊙ blood exposed to lead equivalent to 30, 40, and 50 μg. per ml. R.B.C.

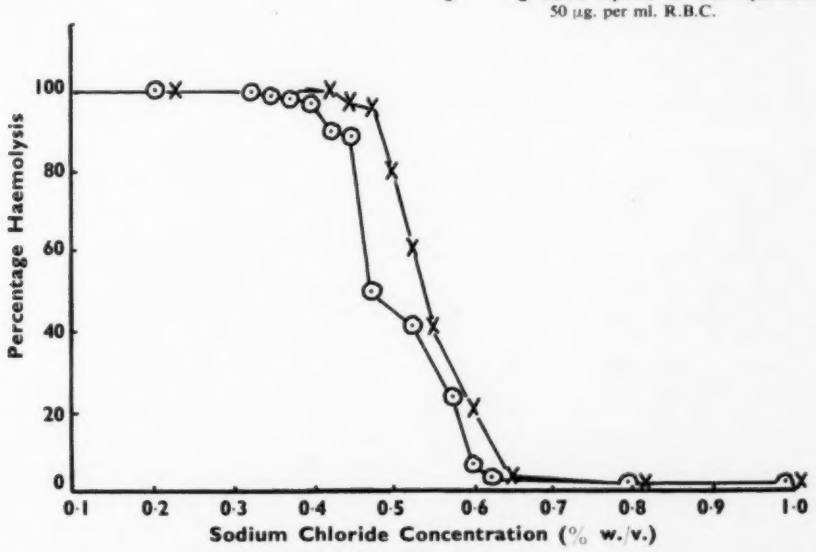


FIG. 4.—Hypotonic haemolysis at 37° C. of a saline suspension of red blood cells exposed to lead chloride equivalent to 10μg. lead per ml. packed red cells for 30 min. The suspension had been allowed to stand at 37° C. for one hour before addition of lead. A control curve for a saline suspension without added lead stood for an identical time is included.

X ——— X control curve
⊙ ——— ⊙ cells exposed to lead for 30 min.

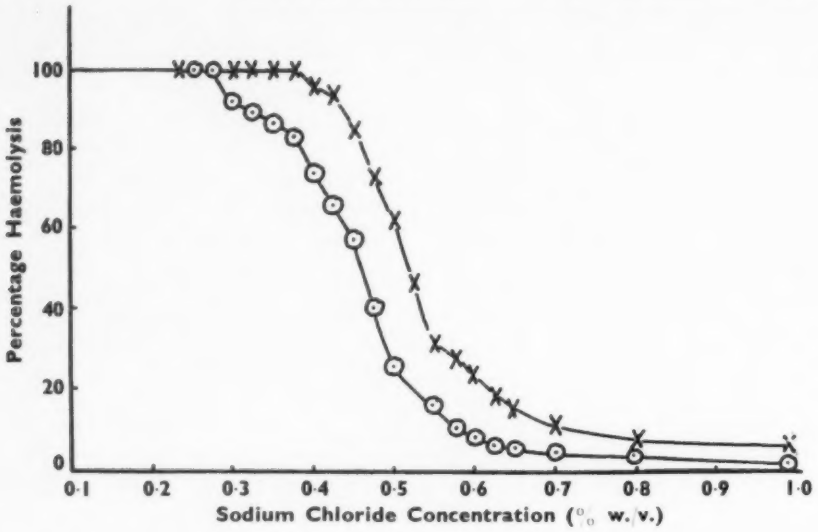


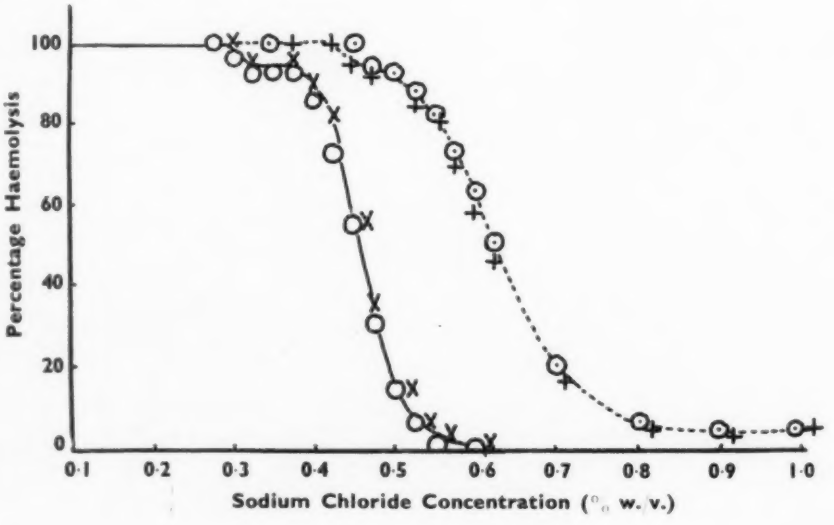
FIG. 5.—Hypotonic haemolysis at 37° C. of a saline suspension of red blood cells exposed to lead chloride equivalent to 10μg. lead per ml. packed red cells for 24 hr. The suspension had been allowed to stand at 37° C. for one hour before addition of lead. A control curve for a saline suspension without added lead stood for an identical time is included.

X ——— X control curve
⊛ ——— ⊛ cells exposed to lead for 24 hr.

This does not arise by inhibition of lead uptake, however, as postulated by Aub, but by a quite different mechanism. Clarkson and Kench (1958) have concluded from detailed kinetic studies that a peptized lead phosphate sol was first produced, which interacted on the cellular membrane to form a precipitate of lead phosphate even when the concentration of added lead was extremely small. The physical changes and behaviour of the erythrocytes can be better understood if the state of the added lead is considered. Many of the data are compatible with the concept of a lead phosphate sol carrying a charge dependent on the relative proportions of lead and phosphate ions present. In solutions containing excess phosphate, the lead sol would be negatively charged, and on attachment to the erythrocyte would raise the negative charge already present. Mutual repulsion of the corpuscles would be strengthened, and hence the rate of sedimentation diminished. In saline suspensions, especially of thrice-washed red blood cells, the concentration of free phosphate ions would be very low, and the net charge on the lead phosphate sol probably reversed. This would account for the more rapid corpuscular uptake of lead from such low phosphate media. Attachment to the corpuscles would partially neutralize the

FIG. 6.—Hypotonic haemolysis at 37° C. of whole blood to which lead chloride equivalent to 10 μg. lead per ml. packed red blood cells had been added and equilibrated for 30 min. and for 24 hr. Control curves for whole blood stood for similar periods of time but not treated with lead are included.

X ——— X Hypotonic haemolysis of whole blood as control for O ——— O curve.
O ——— O Hypotonic haemolysis of whole blood equilibrated for 30 min. with lead.
\+ ——— + Control for ⊛ ——— ⊛
⊛ ——— ⊛ Comparable results following equilibration with lead for 24 hr.



stabilizing negative surface charge, leading to augmented sedimentation rate. It is not at all clear why diminished osmotic fragility should be a consequence of this course of events. Direct inhibition by surface lead of anion and water transport across the corpuscular membrane is discounted by the low ionization of the metal complex. Complementary electron microscopical studies may help towards an understanding of this effect.

Our interpretation depends upon the direction and not on the magnitude of the effects of lead on the sedimentation rate of the erythrocytes: the lack of stoichiometry is evident in Fig. 3 where the rates in the presence of 30, 40, and 50μg. Pb. were indistinguishable from one another. The great difference between the sedimentation rates in NaCl and media containing phosphate (Krebs Ringer bicarbonate solution and whole blood) illustrates the importance of the phosphate groups present, and the changes produced by added lead must be interpreted in terms of the control. The contrasting effect of lead added to NaCl as compared with phosphate-containing media was observed consistently in several experiments. This phenomenon is not due merely to modification of the medium, since in every case the added lead is rapidly taken up by the corpuscles.

Our results suggest that the protective action of plasma and of other solutions containing excess phosphate is due to the approaching lead phosphate sol possessing a negative charge in such media and not to a prevention of lead uptake by the phosphate as suggested by earlier workers. It also seems unlikely that lead added to red cells in whole blood under conditions similar to the state *in vivo* will produce any detectable damage to the cell. One must conclude that the injury caused by lead to the red blood corpuscles—and evidence for increased haemolysis has been mentioned earlier in this paper —must occur during and be confined to formative stages in the bone marrow. Here occur intracellularly the enzymatic disturbances which result in restricted production of haem and probably punctate basophilia. Dialysis studies (Clarkson and Kench, 1958) have located intracellular lead incorporated presumably during haemopoiesis. Such lead, if biochemically active, would undoubtedly be in a form other than phosphate, since a peptized phosphate sol would not be available for reaction with essential groups in enzymes such as carboxylate, sulphydryl, and phosphate. How lead can enter the immature cells to produce these biochemical and morphological changes is a problem for future study.

Summary

A study is described of the interaction of lead with human erythrocytes as portrayed by the sedimentation rate and osmotic fragility.

Sedimentation rates were reduced for red blood cells exposed to lead in media containing excess phosphate, *e.g.*, whole blood and Krebs Ringer bicarbonate solution. An increased sedimentation rate was observed in erythrocytes exposed to lead chloride in saline.

Little change in the osmotic fragility of red blood corpuscles was detectable when lead was added in the presence of excess phosphate, but in saline there was a marked increase in resistance to haemolysis in hypotonic saline.

It is concluded that *in vivo* plasma lead will cause only minimal changes in the fragility of circulating erythrocytes: all injurious effects (inhibition of haem synthesis and morphological abnormalities such as punctate basophilia) will have already been produced in precursor cells developing in the bone marrow.

Our thanks are due to Professor R. E. Lane for his continued interest in these investigations. We are indebted to Dr. R. L. Turner for helpful discussions and to Mr. H. V. Stevenson for technical assistance. We are grateful to the Medical Research Council who provided generous support for the work in a grant to one of us (T. W. C.) and in defraying research expenses.

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THE EFFECTS OF BURSTS OF LOUD NOISE ON A CONTINUOUS VISUAL TASK

BY

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Nowadays there are many situations in which men doing mental work with visual material are subjected to brief loud noises heard at irregular intervals from a source close at hand. The study described in this paper was directed at two questions arising from these working conditions. (1) Does the noise interfere with levels of individual efficiency ? (2) If any such adverse effects are evident, are the men already making the maximum effort to deal with the distracting noise or could they be warned and encouraged to overcome it ? (It is often useful to detect as far as possible any differences between what people will do and what they can do.)

Research into the psychological effects of loud noise on human performance has generally been concerned with noise presented over a moderately prolonged period of time—a few minutes, an hour, or even a working day. Smith (1950), however, used bursts of sound lasting from 10 to 50 seconds, given at irregular intervals to a group doing paper tests of matching and form-assembling. The intensity was 100 db., heard through speakers, one on either side of the test room. The subjects' hearing was not tested, but a control group was used. Test results from the experimental group were quantitatively better and qualitatively worse than the controls, but it was concluded that the differences were negligible for practical purposes. A report from the National Defence Research Council (U.S.A.) in 1942 described two experiments to test the hypothesis that sudden and continued loud sounds, such as encountered in battle, might have harmful effects on the accuracy of tracking and range finding. The sounds lasted two to three minutes, intensities ranged from 100 to 130 db. Subjects indicated physiological effects, but test performance did not deteriorate. The present author has not been able to trace any work demonstrating psychological methods of combating the effects of short bursts of sound.

The experiment described below was designed primarily to discover whether brief loud noise affected performance in a visual task. It was followed by a further test to investigate whether alerting and encouraging the operator could assist in combating these effects.

Method

A task was required in which signals for action appeared very frequently at irregular time intervals so that the noise might occur either at busy or slack periods. The test chosen was a version of the multi-channel test (Mackworth and Mackworth, 1956) in which subjects matched pairs of cards by counting the number of similar symbols on them. There were six items on every card and therefore six comparisons had to be made between each pair of cards. These problems were shown on a vertical screen.

In the present version, 10 stationary cards were arranged in a row along the top of the display window. Beneath these fixed cards were other cards which appeared in 10 channels and moved slowly upwards until they disappeared from view. The entire content of one of these moving cards was fully visible for five seconds, but some part of the card was visible for 20 seconds. Each of these cards had to be compared with its corresponding stationary card. During the four-minute test run there were 70 such comparisons to be made; these occurred irregularly. The display was constantly changing. Sometimes comparisons could be taken slowly—when perhaps three comparisons were needed and none of these were completely synchronous with each other. Sometimes, however, a burst of activity might mean as many as 10 comparisons showing on the display at the same time, and possibly three of these might arrive almost simultaneously.

A tape recording of an explosive sound was available for the noise and all the noise bursts given were copies of this record. Each burst lasted approximately four seconds and its peak intensity, which was approximately 100 db., came on for rather more than one second. Oscillograms of typical bursts are shown in Fig. 1, which indicates the general envelope of a whole burst. Fig. 2 is from a small part of an oscillogram taken on an extended time base. Although the main components of the sound were high in frequency, they were modulated at a low frequency (less than 100 cycles). Fig. 3 shows

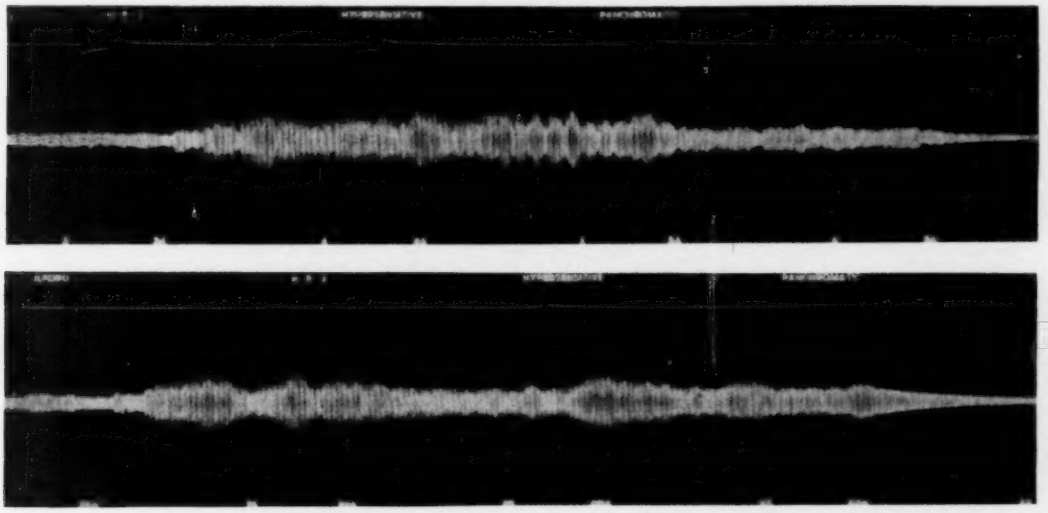

FIG. 1.—Oscillograms of two of the noise bursts. Time base is 1·6 inches per second.

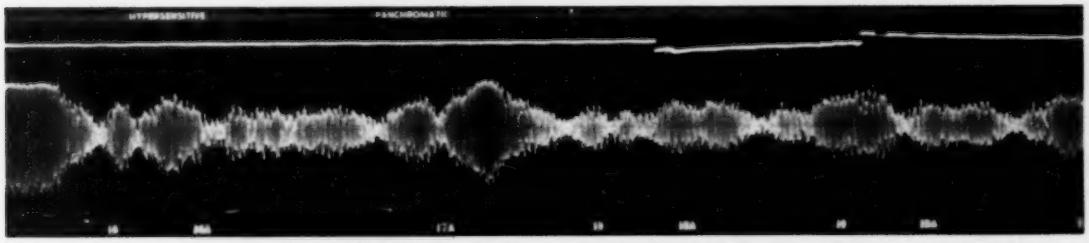

FIG. 2.—A small part of a burst, taken on a time base of 11 inches per second.

an approximate analysis of the sound during the first and second seconds of its duration. At first the main components were centred around 300 cycles, and one second later around 2,000 cycles. For comparison, the spectrum which would have been provided by white noise is included in Fig. 3. The filter used for the approximate frequency analysis was a Wein bridge tuned circuit analogue, and therefore has no definite "band width". It was adjusted, at each tuning point, so that the band width between the 3 db. points was one-fifth of the mid-band frequency. The microphone, amplifier, and oscilloscope used for this analysis were not calibrated, and consequently the figures have only relative value.

Four versions of the test film were made:

(1) With four bursts of sound, one at each of two busy periods and one at each of two slack periods;

(2) A repeat of (1), but with the noise at different stages in the visual task.

(3) As for (1) but with a warning light alerting the subject three seconds before each bang.

(4) Silent—no bangs, a control condition.

The purpose of (3) was to discover whether immediate warning cues influenced responses in noisy conditions. All subjects did all versions, in an order determined by a Latin square design. They were instructed and tested individually.

The film was presented by back projection on to a screen set in a booth which was constructed of wood and insulating board, lined with felt, and had a floor area of 4 sq. feet. Sound was introduced through a loudspeaker below the screen and the subject sat at the back of the booth, facing the screen. By this arrangement of subject and speaker in a small damped area it was hoped that the bursts of sound would be uniform for each man regardless of his height and breadth. Subjects were not, however, sitting in a silent room: there was moderate (70 db.) noise from a ventilator fan in the booth wall and the film projector outside the booth. They used a hand microphone and their answers were recorded. The test was presented on magnetic sound film to ensure that the noise bursts occurred always at the same instants during this visual task.

Two groups, *A* and *B*, each of 12 Naval ratings, were tested. Age ranges were 18 to 25. All subjects had normal hearing. Audiograms of each man were taken beforehand and again the day after the test; no significant changes were noted.

Test-practice runs were given at both slow and normal speeds, including one noise run at the normal 24 frames per second. The men were sufficiently familiar with the noise bursts for startle to be excluded, yet not familiar enough to have developed an attitude of hearing without

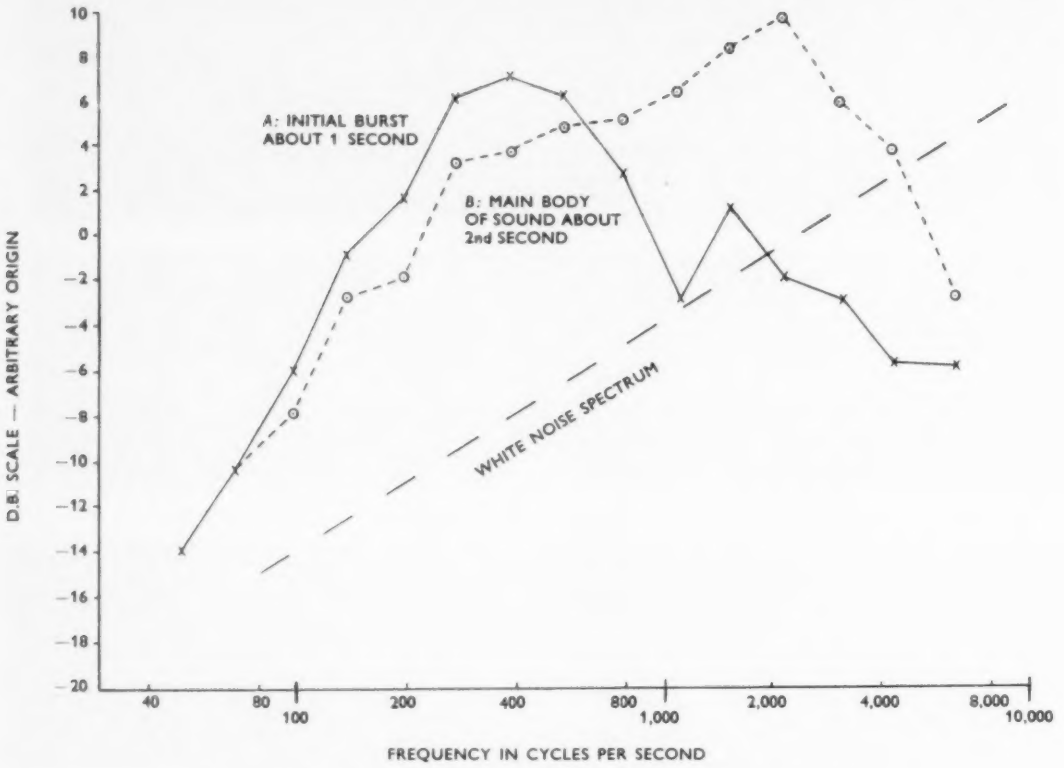

FIG. 3.—Approximate frequency analysis of the sound during first two seconds.

conscious awareness of the sounds. The red warning light was also demonstrated.

There were differences in the instructions given to the two groups. It was hoped that these differences would indicate whether any performance deterioration due to noise was involuntary. Group *A* received an explanation that the task cards were allied to the flight plans of aeroplanes and the symbols on the cards to relevant pieces of information. The noise was described as resembling the sound of a mild explosion.

Group *B* received the same explanation, but in addition they had further instructions, encouragement, and day by day knowledge of results. On the third day of their practice runs subjects were informed, " When we were giving this test a few weeks ago, we discovered people did rather less well just after the noise occurred. Either they missed out more cards, or they made more mistakes in the few seconds following a burst of noise. So when you hear a bang, do make a special effort to keep to your normal steady performance, and not to be put off, even for a second ". Just before the start of the film subjects were also told, " Remember to keep on as usual immediately after the noise ". The actual test was on the fourth day and subjects were again encouraged to maintain their usual performances despite the noise.

When the broad picture of the quality of the taking of decisions by the two groups of subjects was inspected, it was found that the general average scores showed no difference between the noise runs and the silent control runs. (From an analysis of variance there was no significant difference between the overall performances of the two Groups *A* and *B*, and none between the group results to the four test versions, although there was considerable variation between subjects, with *F* ratio 32·75, 23 and 48 d.f., $P < 0{\cdot}001$.)

A more detailed consideration of the scores, however, brought out some clear-cut differences by an analysis which concentrated on the accuracy shown during the half-minute or so of the task immediately following each bang. This serial analysis of a particular time sample taken from one small key section of the records resembles in some respects the step-by-step analysis of key incidents previously found useful in the quite different problem of the experimental analysis of car driving skill. There the key incident was the corner rather than the bang, and each half-minute analysis included individual performance just before as well as just after the corner (Lewis, 1956).

Results

1. Key Incident Analysis for Both Groups.—Nineteen of the 24 men tested did better under the silent condition. Four men were better in noise and the

TABLE 1

EFFECTS OF NOISE FOR ONE TO SIX CARDS AFTER EACH BURST

Responses	Cards and Times					
	1st within 14 Seconds	2nd within 18 Seconds	3rd within 26 Seconds	4th within 28 Seconds	5th within 31 Seconds	6th within 32 Seconds
Total number for each group of subjects	144	144	144	144	144	120
Group A ($N = 12$) :						
Correct on noise versions, incorrect on silent version equivalents	12	16	26	26	15	25
Correct on silent version, incorrect on noise version equivalents	37	32	31	23	21	25
Differences	25	16	5	—3	6	0
Group B ($N = 12$) :						
Correct on noise versions, incorrect on silent version equivalents	18	22	21	16	26	25
Correct on silent version, incorrect on noise version equivalents	24	37	26	26	26	19
Differences	6	15	5	10	0	—6
Differences for *A* and *B* combined	31	31	10	7	6	—6

remaining subject was unaffected. These were the results for the card comparisons immediately after each noise burst, compared with their counterparts in the silent control. Better performance usually entailed reporting more signals rather than giving fewer incorrect answers.

2. Detailed Trend Analysis, Group *A* (No Information).—Table 1 shows the distribution of responses for the first to sixth cards after noise. It is clear that immediately after a burst the performance of Group *A* was affected. Fig. 4 shows all the correct answers for each of six cards after noise compared with equivalent cards from the silent version. Three times as many correct responses were made to the first of these cards during the silent control compared with those during noise. Similarly for the second card, there were twice as many correct answers in silence compared with during noise (Table 1). Recovery was rapid from these marked changes, and by about 27 seconds after the bang no such difference remained between the noise and silent conditions. It may be noted that the six cards selected followed each other so swiftly that even in the condition without noise the subjects had some difficulty in remaining accurate towards the end of this short series of decisions.

3. Detailed Trend Analysis, Group *B* (with Information).—The performance of Group *B* also showed detrimental effects in the noise versions. The differences in responses after noise compared with

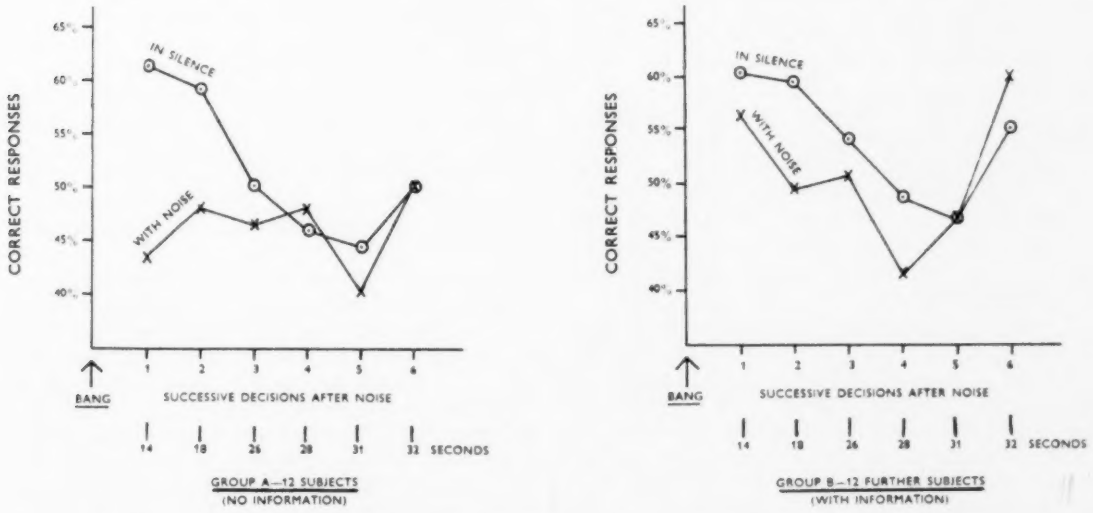

FIG. 4.—Effects of noise: correct responses (percentages) to six decisions after noise and to equivalent cards on the silent version.

equivalent cards on the silent run were less marked initially, but lasted longer than those shown by Group *A*. Fig. 4 illustrates these results. In the situation where subjects were far more conscious of the distraction danger, this wariness did not prevent deterioration.

4. Effects of Warning Light and Visual Task Demands.—Both groups of subjects showed a trend, not statistically significant at $P < 0.05$ level, towards being less accurate with the warning light; it seemed that the warning was not an aid but may even have been a distraction. Unexpectedly, there were no statistically valid signs of the detrimental effects of noise being greater at busy spells for any given decision.

5. Individual Differences.—Although Group *B* still failed to produce a statistically significant improvement on the results from the other group, the significant differences between subjects, and the differing group response curves after noise, suggested that individual performances would be interesting.

From individual response curves, only one subject in Group *A* did not show the adverse effects after hearing the bursts. Four subjects in Group *B* responded successfully to the revised instructions by maintaining or improving their performance level after noise, although their improved results were insufficient to influence those of the group as a whole. They showed, however, that a third of this group was able to profit from knowledge of possible effects of loud noise (or distraction) and from encouragement to overcome these effects.

6. Recovery Time.—It was feasible for the effects after each noise burst to be assessed in terms of the maximum time available for response. This was done by calculating in seconds the largest of the intervals of time between a bang and the cards immediately after it.

The results demonstrated that effects on performance in the present experimental situation must have occurred in less than 28 seconds for Group *A* and within 31 seconds for Group *B* (see Fig. 4). Broadly, it took periods of up to half a minute from the onset of the noise for performance to recover in the sense of returning to the level achieved by the same men without noise.

7. Subjects' Comments.—All 24 subjects were questioned about the test and noise after all testing was over. No one found the visual task intrinsically difficult, but six men referred to the high speed required. Only three found the noise irritating, but other comments on the noise varied from "unduly quiet" through "loud enough" to "could still hear myself think, which is all that matters". No physical symptoms were reported. Five subjects found the red warning light more distracting than the bursts of noise. Opinions were evenly divided on the need for extra concentration during noise.

Although no special emphasis is placed on these subjective reactions to the test and the noise, it is worth noting that all the men assumed that this general problem of effects of loud noise heard during pressure of work was a problem which they were constantly experiencing as Naval personnel.

Discussion

The test conditions for Group *A* left undecided the question whether subjects were merely reluctant or actually unable to keep responding normally during and immediately after the noise. The revised conditions for Group *B* excluded the possibility of the men succumbing to the harassing effects of the bangs simply because they were unaware of being harassed.

It seems reasonable that people may feel disinclined to speak their responses during loud bangs, even when particularly motivated to do so. But here the brevity of the noise effects and the rapid rate of recovery indicated that the subjects in both groups were trying to keep up with the visual display. There is little evidence to support the idea of a simple reluctance to respond.

It appears that most of those tested were actually unable to avoid showing some effects from brief loud noises whilst doing a task of the decision-taking type. On the other hand, the performances of the five exceptional subjects make it clear that there are men who have the ability to combat these effects.

It might be thought that if all the subjects kept to their fastest working rate throughout, they would then have time to suspend their task briefly around noisy periods without missing any signals. There were slack periods of the test when few decisions had to be made and subjects should have been able to pause, without missing a signal, at the time when distraction occurred. Instead they reduced their rate of work at these periods, not leaving themselves any convenient gaps, and therefore even at slow signal input rates, their attention was sustained and could be disturbed by noise.

The test was not only varied by differing instructions and rate of work, but also by the warning light system which was found to be unhelpful. Variations in the task situation did not, therefore, alter the overall results as they would certainly have done in operations such as watchkeeping. It is apparent that the noise distraction was the dominant factor. If the short reaction to bursts of noise is a fundamental one, it may be independent of current activity of the kind required in the present experiment and not due to the shock of an unusual noise for which

the operator is entirely unprepared. Despite his positive efforts he is unable to act normally—unless he belongs to the minority quickly reacting group. One hypothesis is that when subjected to noise of this type a person's perceptual mechanism is less affected than his response mechanism. (In this connexion the evidence of Coleman and Krauskopf (1956) indicates that the visual function is not likely to be disturbed by noise intensities around 100 db.)

From the point of view of practical application, it cannot be expected that the sustained effort expended on four-minute tests could be kept up for very long. Four brief noises at a maximum of 100 db. here prevented most of the subjects from maintaining during a short period the standard of work they had established when the noises were absent. Therefore they could not be expected to maintain it during longer periods. It may be that sufficient familiarity with a regularly occurring noise eventually overrules any distracting effects. But in those operational situations where there is intermittent loud noise, it does appear that there is a danger of assuming that activity will be normal and needs no extra check for accuracy. Supervisors and operators should be aware of the distracting hazards of this kind of loud noise.

A further experiment is now in progress, in which a shorter and louder noise is used than the one described above. Bursts repeating at brief intervals have also been introduced as another aspect of the problem of loud noise. It would be of great interest also to compare the performances of men who are exposed to intermittent noise every working day—perhaps in industrial conditions—with performances from men who are exposed to it only occasionally.

Conclusions

From the significant results of a group of young Naval ratings it may be inferred that some, at least, of those men who must rapidly take a series of quick decisions within range of short bursts of a moderately loud noise (to which they are accustomed but not completely adapted) may have a temporary loss of working efficiency lasting up to half a minute after each noise. This trend towards some loss of efficiency can occur whether or not the men are made aware of the possibility of deterioration. There will probably be a tendency to miss signals altogether rather than to report them incorrectly.

It will be worth while acquainting all men who have to respond to continuous visual signals against a background of occasional loud noises of the particular alertness needed to avoid missing signals immediately after hearing the noise. This information will not cause further deterioration but will enable a minority to overcome the distracting effects.

Summary

The effects of short bursts of loud sound on the performance of men doing a visual matching task are described. The task ran for four minutes and four bursts of noise were given at irregularly-spaced intervals during that time. Each of these bursts lasted four seconds and reached a peak intensity of 100 db., the noise being widely distributed over the frequency spectrum.

Two groups of subjects were tested. One group was given more information about the test than the other and also received verbal encouragement and knowledge of results. The aim of these apparently more favourable testing conditions was to discover whether any deterioration in performance after noise could be lessened by alerting the men to the danger and encouraging them to overcome it.

The main conclusion is that bursts of loud noise heard by men engaged on a visual task caused immediate deterioration in the performance of most of them, with complete recovery during the next half-minute.

The results also demonstrate a general tendency for performance of this type of work to deteriorate immediately after brief loud noise even when operators are aware of this possibility and are attempting to deal with it. In the experiment small variations in the task, such as a warning light, did not prevent deterioration. Prior verbal alerting and instruction to some operators enabled only a third of these to avoid the detrimental effects.

The author wishes to express her gratitude to Dr. N. H. Mackworth, Director, M.R.C. Applied Psychology Research Unit, for his guidance and interest in this study; and to Mr. D. Broadbent, Dr. A Carpenter, and Mr. D. Simmonds for their considerable technical help and advice.

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A METHOD FOR THE DETERMINATION OF TRINITROTOLUENE IN AIR

BY

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From the Ministry of Supply

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Properties of Trinitrotoluene

Trinitrotoluene is the high explosive used as a main bursting charge in shells, mines, and bombs.

It is a potent poison for the liver, blood, and blood-forming organs, and fatalities have been recorded from toxic anaemia, toxic jaundice, and acute yellow atrophy of the liver. From 1916 to 1918 there were notified 403 cases of toxic jaundice, 105 (26%) being fatal, and 15 cases of toxic anaemia, all of which were fatal. In the second world war, toxic jaundice cases numbered 116, with 25 deaths (21·5%), and toxic anaemia cases 24, with 15 deaths. These figures take no account of the lesser degrees of intoxication where further deterioration was halted by timely intervention.

2 : 4 : 6-Trinitrotoluene is one of six isomers, and has the formula $C_6H_2(NO_2)_3CH_3$. It is obtained by nitration of the coal-tar product toluene and melts at 81 to 82° C. It is practically insoluble in water, but is soluble in fat and many organic solvents. The vapour pressure at room temperature is very low. Nevertheless, according to *Occupation and Health* (International Labour Office, 1934), it is capable in the dry state of giving off fumes into the atmosphere at a temperature as low as 32° C. Furthermore, the low vapour pressure means that any vapour arising from hot melted trinitrotoluene will readily condense into fume on meeting cooler air and collect as a fine powder on any surface colder than 70° C. Air pollution is for all practical purposes in the form of suspended solids.

Inhalation is by far the most important mode of entry to the body. Stewart, Witts, Higgins, and O'Brien (1945), in observations on persons exposed to contact of different kinds, found that the greatest effects occurred in those who were working in melt houses where there was the most intense exposure to fume. The maximum allowable concentration for an eight-hour day and with a normal amount of physical effort is fixed in America at 1·5 mg. per cubic metre of air. In this country, however, it has generally been accepted that a figure of 2 mg. is permissible. These figures, of course, are always capable of modification when the nature of the work differs from average conditions.

Factors Influencing Dosage

Physical Exertion.—The maximum allowable concentration figures are calculated on the basis of an ordinary amount of physical exertion. When effort is intensified, as by frequently going up and down stairs, or by having to carry heavy loads, pulmonary ventilation is greatly increased. If this should coincide with periods of unduly heavy air contamination the worker will be exposed to the risk of inhaling a much greater quantity of dust and fume.

Davies (1952), in reviewing recent work on the alveolar retention of dust particles, concludes that the maximum retention—which is between 50 and 60% of the dust inhaled—occurs with particles of 1·5 to 2μ diameter, and that the proportion of 5μ particles retained falls to about 30% or less. It is generally agreed that still larger particles are for the most part held up in the upper respiratory tract and are rejected by the action of ciliated epithelium, but a fair proportion of these may ultimately be swallowed, and so, as far as trinitrotoluene is concerned, contribute to the effect of its toxicity.

Warner and Chrenko (1943) made some observations on particle size distributions of trinitrotoluene dust in filling shops. They found no particles larger than 5μ in diameter and nearly all the particles measured were less than 2μ in size. If this evidence be accepted, it follows that practically the whole of trinitrotoluene dust and fume may be considered as coming within the respirable range. If so, it becomes unnecessary to insist on isokinetic conditions when it comes to air sampling. Also mass concentration can be taken as a reasonably good

measure of the inhalation hazard. Some confirmation of this view is afforded by experiments carried out in 1944 to determine the amount of air-borne trinitrotoluene retained and expired by workers. Using a modified service respirator, it was found that on an average 76% of the trinitrotoluene originally in the inspired air was retained within the body, whether breathing was by nose or mouth. Similar figures have been obtained in other dusty occupations for particles of the same size (van Wijk and Patterson, 1940).

Ventilation.—This prevalence of dust and fume of a dangerous respirable character demands adequate ventilation. Trinitrotoluene is a powerful explosive, so that the shops in which it is handled are all surrounded by high earth banks and blast walls. These very materially reduce natural ventilation. Since all shops are not necessarily treated alike it is not impossible to have two of similar construction, carrying out identical processes, and yet varying markedly in the degree of air pollution. Weather conditions contribute to the difficulties, and there may be alterations almost from hour to hour. Changes of wind direction are not so important as the effects of the protective banking, but rises in temperature and in relative humidity are both capable of leading to noticeable variations. Within the shops the distribution of dust and fume is by no means uniform. The highest concentrations are generally found in the upper levels. Investigations in 1952 demonstrated that in enclosed spaces there was a tendency for trinitrotoluene to exist in the atmosphere in strata, so that it was quite possible to find a layer rich in dust and another layer poor in dust relatively close to each other.

The processes themselves and the layouts in the shops vary. The exposure of workers can vary according to the stage of the cycle of work on which they are engaged, and it is essential to evaluate concentrations at different points within the shop. The efficiency of local exhaust ventilation is necessarily subject to the over-riding demands of safety from explosion. Moreover, on occasion, the technical requirements of the process are such that it is imperative to maintain the shop temperature at a fixed level for a period and every effort is then made to exclude all draughts from outside. On such occasions ventilation is virtually non-existent. When night shifts were worked and blackout regulations observed, ventilation was further restricted. Observations made during the second world war showed that the concentration of air-borne trinitrotoluene in filling shops was often four or more times as high under blackout conditions as during day operations.

Description of Sampler

The problem of controlling the hazard is basically the prevention of air pollution. This means having a simple method of estimating the concentration of air-borne trinitrotoluene. It must be of an acceptable degree of accuracy, and it must be completely safe, because of the explosive risk. Earlier methods had included the use of the DSIR hand-pump (DSIR Leaflet No. 5, Nitrous Fumes, 1940), along with a varying choice of solvents—solid naphthalene pellets, acetone, different alcohols, a mixture of cyclohexanone and methyl ethyl ketone, and 2-diethylaminoethanol. A variety of reasons precluded the adoption of any one of these procedures as being completely satisfactory. In particular, it was desired to use an automatic means of obtaining the air samples. Because of the risk of explosion an electric motor and vacuum pump could not be used, and recourse was had at first to a water suction pump, with a gas meter to measure the volume of air sampled. But a source of water power was not always sufficiently convenient, and inordinate lengths of rubber tubing frequently became necessary. To overcome these difficulties the collecting unit to be described was evolved by the Chemical Inspectorate and Engineering Departments of R.O.F., Chorley, Ministry of Supply.

Basically, the principle is that of an egg-timer (Fig. 1). The unit consists of two large glass aspirators (*A*) one above the other, interchangeable and interconnected, so that when the known volume of water from the top one is allowed to drain into the lower one an equal volume of air is drawn into the top aspirator. An adjustable assembly (*B*) for containing an absorption train (*C*) (Fig. 2) is fitted, together with a revolution counter (*D*) to record the number of times, during a run, that the aspiration positions are reversed. A small glass cylinder (*E*) (Fig. 4) is fitted to the water outlet of each aspirator in order to ensure a sudden cessation of suction in preference to the gradual decrease which is normally evident. The complete apparatus is tested and calibrated, the rate of suction being controlled by a valve (*F*) (Fig. 3) connected to the suction outlet of the apparatus. The volume of air drawn through the system by each aspirator varies according to the rate of air flow. This is because the reduction in pressure when the water flow rate is increased is not fully compensated by the increase in bubble rate. Since, on completion of the cycle, the internal pressure is automatically equilibrated with atmospheric pressure, the total volume of air entrained is less per cycle than at lower flow rates. Ideally, a very slow flow rate would give the maximum volume entrained per cycle. In practice the flow is maintained at an approximately constant rate of 1 to 2 cubic feet per hour (faster rates tend to cause splashing in a bubbling tube that contains a sintered disc of G.1 porosity) so that the variation is insignificant, provided the apparatus is calibrated at this particular flow rate. The usual practice is to reverse the aspirations about 10 times over a period of 45 to 60 minutes. The total volume of air sampled is usually around 1½ to 2 cubic feet (40 to 56 litres). The absorption train consists of two absorption vessels, inter-connected by polythene tubing (*G*) and attached to the main apparatus by rubber tubing (*H*). The first vessel has the sintered glass plate (*I*)

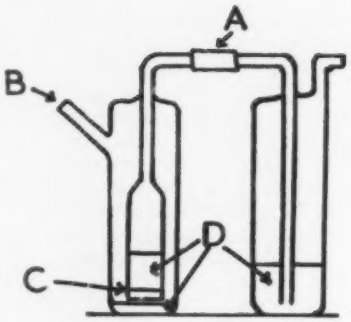

FIG. 2.—Sketch of the arrangements in the absorption train (Fig. 1).
A = Polythene tubing
B = Air intake
C = G.1 sinter
D = Solvent

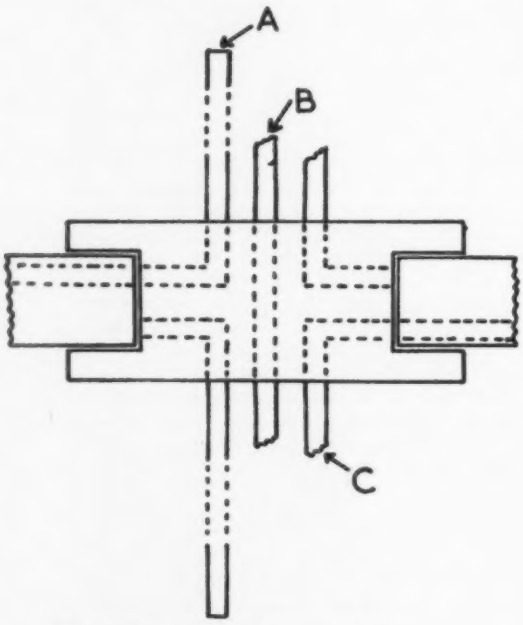

FIG. 3.—Sketch of the arrangements in the inlet valve F (Fig. 1).
A = Suction
B = Water flow
C = Pressure release

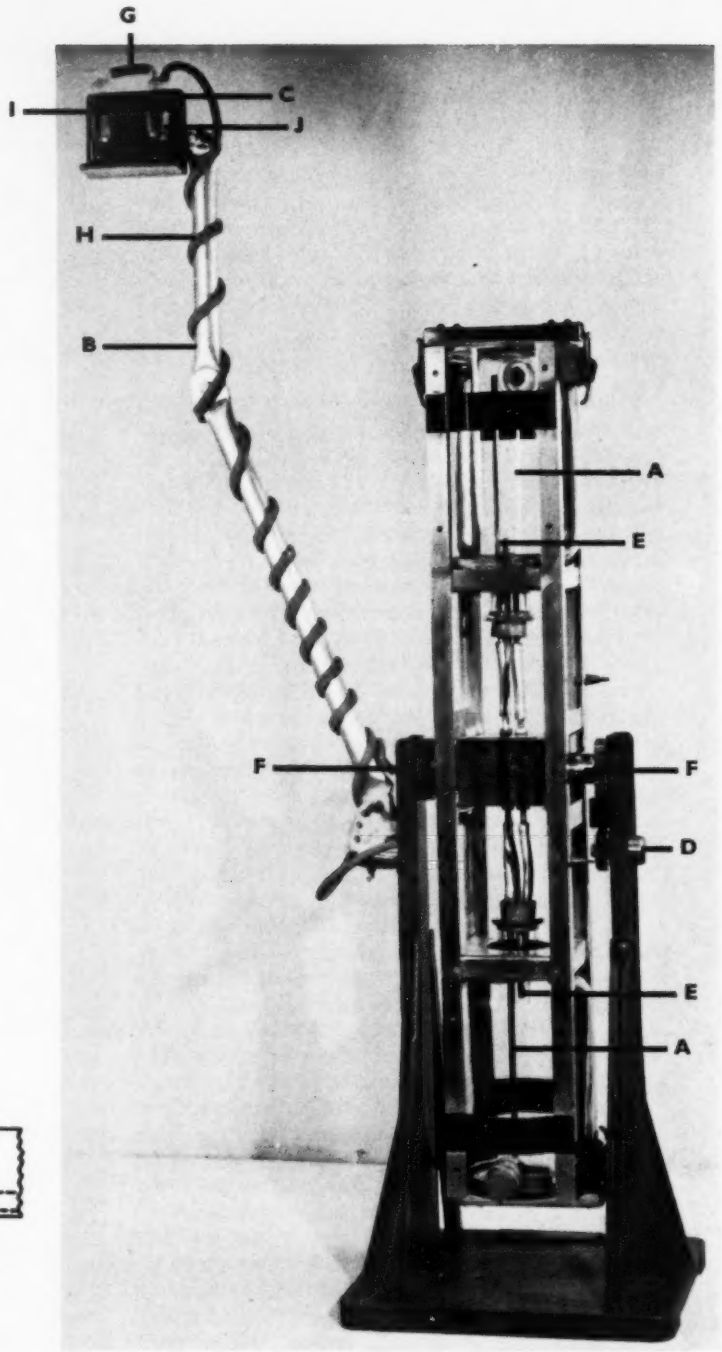

FIG. 1.—The Chorley entraining unit.
A = Aspirator
B = Adjustable assembly
C = Absorption train
D = Revolution counter
E = Glass cylinder
F = Inlet valve
G = Polythene tubing
H = Rubber tubing
I = First vessel, with sintered glass plate
J = Second vessel

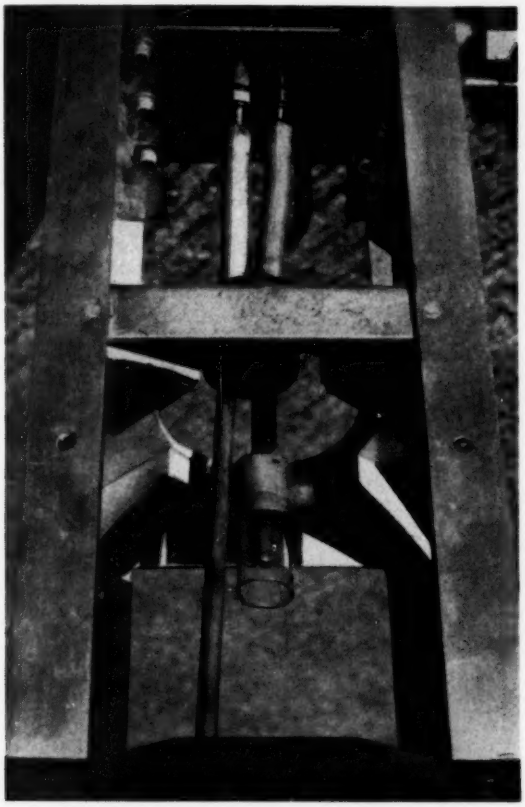

FIG. 4.—The water outlet tube of the aspirators with the cylinder surrounding it to ensure sudden cessation of suction.

(G.1 porosity) to break up the air current and present as large a surface as possible to the solvent. The second vessel (*J*) is only a guard tube, and, in air concentrations of trinitrotoluene so far dealt with, has not been found necessary. The apparatus is very simple to use. It is set up wherever sampling is required, the absorption tubes filled with solvent (2 to 8 ml.), the adjustable arm is fixed at whatever point is desired, and suction is begun and continued by reversing the aspirators in turn at whatever rate of flow is wanted. The volume of air sampled throughout the test is calculated by multiplying the apparatus constant by the figure shown on the revolution counter. As a rule, this is about 1·5 cubic feet of air.

The solvent is ethylene glycol monoethyl ether (" cellosolve ") which must be peroxide-free. It is claimed to give more accurate results than cyclohexanone/methyl ethyl ketone and to permit a much more rapid determination than 2-diethylaminoethanol. Holmes and Wilson (1955) showed that the colour of the violet solution obtained after adding alkali is linearly related to concentrations of trinitrotoluene up to 16 μg. per millilitre of solvent. Colour fading is not important, provided that the alkali is added after absorption of the trinitrotoluene in the solution, and the estimation made within an hour of adding the alkali. The moisture content of the air drawn through the sample was found to have no serious effect on the results.

The solvent is transferred from the bubbling tube to a 10-ml. glass-stoppered measuring cylinder, and 0·1 ml. of a 25% solution of potassium hydroxide added to produce a clear violet colour. The mixture is then made up to 10 ml. by the addition of ethylene glycol monoethyl ether which has been used to wash out the absorption tube. After shaking thoroughly, it is allowed to stand for 15 minutes before colorimetric estimation. Should the test sample produce too deep a colour, it may be diluted with ethylene glycol monoethyl ether, but the potassium hydroxide concentration must be maintained at 0·1 ml. of 25% potassium hydroxide per 10 ml. of sample.

Air samples can be taken as and when required, and can be submitted at leisure to colorimetric estimation. A Hilger photo-electric absorptiometer is used fitted with a tungsten filament lamp and " calorex " heat-resisting filters No. H.503. Using 1 cm. cells and Ilford 604 green filters, it is set at 1·0 with water against a blank consisting of ethylene glycol monoethyl ether plus 0·1 ml. of 25% potassium hydroxide per 10 ml. of solvent. A graph is prepared by measuring the estimation of a series of standards containing 2, 4, 8, 12, and 16 micrograms of trinitrotoluene per millilitre of solvent. From this graph and a knowledge of the volume of air sampled, the atmospheric trinitrotoluene concentration can be calculated.

By selecting a suitable solvent the apparatus can be used for determining the concentration of other airborne contaminants, as has been done with tetryl.

Permission to publish this paper has been granted by the Ministry of Supply and our thanks are also due to Dr. T. Bedford for advice on its preparation.

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MISCELLANEA

Some Enquiries into the Toxicology of Zinc Stearate

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At the International Congress of Industrial Medicine in Naples (Noro and Uotila, 1954), it was stated that " the inhalation of zinc stearate dust is known as a cause of pneumonia in children, but its effects in the working environment are not so well known. The authors describe the fatal case of a worker employed for 29 years in a rubber plant. Clinical examination and necropsy showed diffuse fibrosis of the lungs. Histological tests for zinc were positive ". These authors (Uotila and Noro, 1957) have since given some further details of their patient, who was first seen by them in July, 1952, after having spent 29 years as a rubber cutter using zinc stearate powder in his work. From the autumn of 1951 he had increasing dyspnoea on exertion, cough, and much sputum. When examined, his general condition was considered fairly good, he had a desquamative dermatitis, clubbed fingers, and " watch-glass " nails. A radiograph of the chest showed slight thickening of the left pleura diminishing towards the apex; small nodules radiating from the hilum; emphysema on the right side posteriorly; and enlarged hilar shadows that were considered to be vascular and not lymphoid. A diagnosis of " pneumoconiosis with probable heart failure" was made. He was in hospital for two further periods and died in June, 1954, approximately two years after he was first examined and after his last exposure to dust. At necropsy the lungs were more fleshy than normal, especially the upper lobes, but without calcification or fibrous bands; the lower lobes showed slight oedema: each ventricle of the heart was 8 mm. thick: the liver was granular and there was ascites. Histological examination of the lungs showed old bleeding and a notable increase of connective tissue with abundant chronic inflammation in which were foreign-body giant cells. A test for zinc showed numerous granules and needles in the connective tissue that contained the metal.

In 1925 a committee on accidents from zinc stearate dusting powders appointed by the Board of Trustees of the American Medical Association reported that as the result of a questionnaire they had received reports of 131 cases of poisoning, 28 of which had terminated fatally. They had also heard of many others unofficially. They recommended that all manufacturers of zinc stearate powders for infants should use a self-closing container of a type which does not lend itself to manipulation by an infant, and should place a uniform caution label on the container. They also recommended that the use of zinc stearate as a dusting powder for infants should be discouraged by the medical profession because of lack of therapeutic evidence of its value. Murray (1926), in recording 60 cases of drug poisoning in infants, stated that one fatality, out of a total of three cases, resulted from the aspiration and ingestion of zinc stearate powder. A baby of 14 months was taken to hospital immediately, she developed a diffuse bronchopneumonia next day, and died in less than a further 24 hours. No record of poisoning by zinc stearate powder has been found in the British literature, and none of the many British paediatricians who have been asked has heard of babies suffering from pneumonia due to this powder.

Zinc stearate is used commercially as a substitute for talc in the rubber tyre industry to prevent adhesion. H.M. Factory Department has no evidence that any disability has been caused by its use, but I know of no examinations for possible harmful effects. Stearate kindly supplied by the management of a rubber tyre company was used in the experiments described here.

Experimental

Zinc stearate powder was suspended in tap water and autoclaved. Approximately 100 mg. of the powder suspended in 1 ml. water was injected into the lungs through the larynx of six rats anaesthetized with ether. All the animals died within 10 minutes. Approximately 100 mg. was injected into the peritoneal cavity of six cavies. All the animals became rapidly unwell and two died within a few hours: the others appeared quite normal next day and remained so until they were killed at intervals up to 35 days. All but one, killed at the latest date, showed small granulomata in the peritoneum. Examination of the suspension showed that the stearate was difficult to keep suspended in water, and the fluid was notably acid. All further experiments were therefore done with zinc stearate suspended and autoclaved in a mixture of skimmed milk and saline, and the dose was halved.

Fifty rats were given approximately 50 mg. of zinc stearate suspended in 1 ml. and injected into the lungs through the larynx under ether anaesthesia. Twenty animals died within less than 24 hours, most of them within an hour. Those that were examined showed severe oedema and congestion of the lungs and sometimes small haemorrhages. Animals that survived more than 24 hours appeared quite normal until the time they were killed. Animals killed seven days after injection showed small cellular islands of histiocytes scattered through the lungs. None of the injected dust was visible

FIG. 1.—Peritoneal granuloma in cavy after 28 days. Stained with haematoxylin and eosin. × 25 approximately.

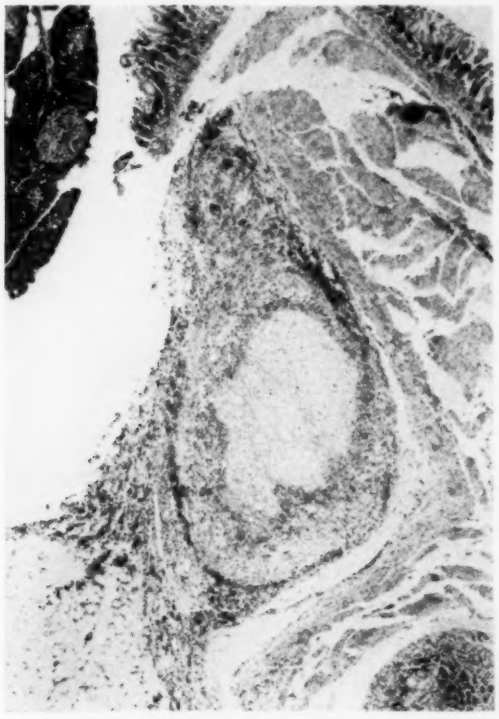

FIG. 2.—Peritoneal granuloma after 42 days. Stained with haematoxylin and eosin. × 30 approximately.

in ordinary paraffin sections, but it is possible that some was still present, since it was later found that the stearate is moderately soluble in fat solvents. Animals killed 14 days or longer after the injection showed no abnormality in the lungs. Rats were killed up to 259 days after the injection and in none was any fibrosis detected in the lungs.

Six cavies were given 50 mg. suspended in 1 ml. water and injected into the peritoneal cavity. None of them showed any apparent ill effects. One animal killed at seven days showed a few small white nodules in the peritoneum that on section had a granulomatous character with a centre of polymorphonuclear leucocytes. After 14 days the stearate lay in a mass of dead cells surrounded by a layer of histiocytes and an outer layer of early fibroblastic proliferation. At 28 days the small granulomata were slightly more defined (Fig. 1). At 42 days a formless or crystalline centre was ringed round by histiocytes outside which was a narrow band of young fibrous tissue (Fig. 2). At 100 and 105 days nothing abnormal was visible in the peritoneum, and no granulomatous or fibrous reaction was found in sections.

Discussion

From these experiments it appears that zinc stearate in suspension in tap water or in a mixture of skimmed milk and physiological saline is acutely irritant, and in doses of 50 mg. kills nearly half the animals if injected through the larynx into the lungs of rats. Death results from acute oedema of the lungs. Given intraperitoneally to cavies, 100 mg. killed two of six animals within a short time, but 50 mg. was tolerated well.

It appears further that zinc stearate disappears within a period of about a fortnight from the lungs of rats, presumably by processes of phagocytosis and solution. It is therefore not surprising that no fibrosis results in the lungs of these animals after a single injection through the larynx.

In the peritoneum of cavies the powder provokes a granulomatous reaction, at first with a polymorphonuclear leucocytic response. These cells die and are surrounded, and eventually digested, by histiocytes. The stearate remains visible in the peritoneum of cavies much longer than in the lungs of rats, possibly because it is rapidly aggregated into a very few masses, and it can still be found after 42 days enclosed in a ring of histiocytes outside which is a narrow zone of fibroblastic activity. However, somewhere between the 42nd and the 100th days the stearate disappears and the granulomatous process regresses until no sign of it can be found.

These experiments, then, while suggesting that inhalation of zinc stearate might produce acute inflammation of the upper respiratory tract or of the lungs, provide no evidence of any fibrogenic permanent effect. Indeed, its solubility suggests that such an effect is unlikely to occur.

MISCELLANEA

Some Enquiries into the Toxicology of Zinc Stearate

H. E. HARDING

From the Department of Pathology, Salisbury General Hospital

(RECEIVED FOR PUBLICATION OCTOBER 23, 1957)

At the International Congress of Industrial Medicine in Naples (Noro and Uotila, 1954), it was stated that " the inhalation of zinc stearate dust is known as a cause of pneumonia in children, but its effects in the working environment are not so well known. The authors describe the fatal case of a worker employed for 29 years in a rubber plant. Clinical examination and necropsy showed diffuse fibrosis of the lungs. Histological tests for zinc were positive ". These authors (Uotila and Noro, 1957) have since given some further details of their patient, who was first seen by them in July, 1952, after having spent 29 years as a rubber cutter using zinc stearate powder in his work. From the autumn of 1951 he had increasing dyspnoea on exertion, cough, and much sputum. When examined, his general condition was considered fairly good, he had a desquamative dermatitis, clubbed fingers, and " watch-glass " nails. A radiograph of the chest showed slight thickening of the left pleura diminishing towards the apex; small nodules radiating from the hilum; emphysema on the right side posteriorly; and enlarged hilar shadows that were considered to be vascular and not lymphoid. A diagnosis of " pneumoconiosis with probable heart failure" was made. He was in hospital for two further periods and died in June, 1954, approximately two years after he was first examined and after his last exposure to dust. At necropsy the lungs were more fleshy than normal, especially the upper lobes, but without calcification or fibrous bands; the lower lobes showed slight oedema: each ventricle of the heart was 8 mm. thick: the liver was granular and there was ascites. Histological examination of the lungs showed old bleeding and a notable increase of connective tissue with abundant chronic inflammation in which were foreign-body giant cells. A test for zinc showed numerous granules and needles in the connective tissue that contained the metal.

In 1925 a committee on accidents from zinc stearate dusting powders appointed by the Board of Trustees of the American Medical Association reported that as the result of a questionnaire they had received reports of 131 cases of poisoning, 28 of which had terminated fatally. They had also heard of many others unofficially. They recommended that all manufacturers of zinc stearate powders for infants should use a self-closing container of a type which does not lend itself to manipulation by an infant, and should place a uniform caution label on the container. They also recommended that the use of zinc stearate as a dusting powder for infants should be discouraged by the medical profession because of lack of therapeutic evidence of its value. Murray (1926), in recording 60 cases of drug poisoning in infants, stated that one fatality, out of a total of three cases, resulted from the aspiration and ingestion of zinc stearate powder. A baby of 14 months was taken to hospital immediately, she developed a diffuse bronchopneumonia next day, and died in less than a further 24 hours. No record of poisoning by zinc stearate powder has been found in the British literature, and none of the many British paediatricians who have been asked has heard of babies suffering from pneumonia due to this powder.

Zinc stearate is used commercially as a substitute for talc in the rubber tyre industry to prevent adhesion. H.M. Factory Department has no evidence that any disability has been caused by its use, but I know of no examinations for possible harmful effects. Stearate kindly supplied by the management of a rubber tyre company was used in the experiments described here.

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Zinc stearate powder was suspended in tap water and autoclaved. Approximately 100 mg. of the powder suspended in 1 ml. water was injected into the lungs through the larynx of six rats anaesthetized with ether. All the animals died within 10 minutes. Approximately 100 mg. was injected into the peritoneal cavity of six cavies. All the animals became rapidly unwell and two died within a few hours: the others appeared quite normal next day and remained so until they were killed at intervals up to 35 days. All but one, killed at the latest date, showed small granulomata in the peritoneum. Examination of the suspension showed that the stearate was difficult to keep suspended in water, and the fluid was notably acid. All further experiments were therefore done with zinc stearate suspended and autoclaved in a mixture of skimmed milk and saline, and the dose was halved.

Fifty rats were given approximately 50 mg. of zinc stearate suspended in 1 ml. and injected into the lungs through the larynx under ether anaesthesia. Twenty animals died within less than 24 hours, most of them within an hour. Those that were examined showed severe oedema and congestion of the lungs and sometimes small haemorrhages. Animals that survived more than 24 hours appeared quite normal until the time they were killed. Animals killed seven days after injection showed small cellular islands of histiocytes scattered through the lungs. None of the injected dust was visible

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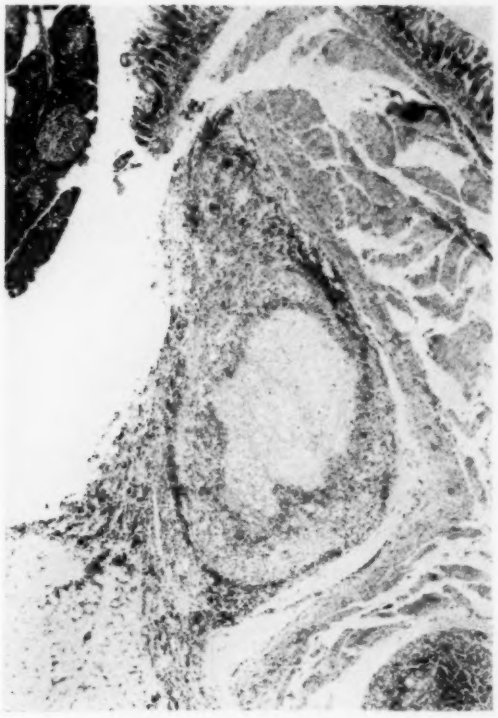

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Summary

Industrial zinc stearate dust in suspension is acutely irritant when injected into the lungs of rats or the peritoneum of cavies.

No fibrosis has resulted from single injections into the lungs of rats or the peritoneum of cavies. Foreign-body granulomata were present for several weeks in the peritoneum but ultimately resolved.

I am grateful to Dr. A. I. G. McLaughlin, H.M. Medical Inspector of Factories, for drawing my attention to the report of Noro and Uotila, for trying to obtain further information from Dr. Noro, and for helping to obtain the sample of zinc stearate. The photomicrographs were taken by Mr. A. W. Collins, F.I.M.L.T.

The expenses of this investigation were met by a grant from the Research Fund of the South-West Metropolitan Regional Hospital Board.

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Murray, L. M. (1926). *Arch. Pediat.*, **43**, 193.
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Welfare at Wall's

The practice of preventive medicine to benefit not only the people initially concerned but also the thousands who eat Wall's ice cream, pies, and sausages is the key to the welfare and medical departments recently opened at Wall's factory at Godley, near Hyde, Cheshire.

The medical department, which is under the direction of Dr. Geoffrey Fletcher, has the usual consulting and treatment rooms, well designed and equipped, surgery, and *x*-ray room. Also, the building contains a bacteriological laboratory in which it is planned to add research in industrial medicine to the routine tests necessary in a food factory.

One of the most important tasks in the medical supervision of those handling food is to ensure care of the hands. By an intensive campaign workers are being trained to report even the most trivial cut or abrasion which is cleaned and one of the department's dressings put on in the surgery. Also, if a worker cuts her hand at home (a high proportion of the workers at Godley are women) the charge hand is trained to spot an unsuitable dressing and send the patient to the medical department to have it exchanged for an approved one. The medical officer has taken great pains to ensure that dressings are suitable for workers on wet and on dry processes, that they are of a pattern which can be securely fastened to the finger or hand, and are distinctive.

All new employees have a medical interview, and also those returning after an illness. In cooperation with family doctors certain treatments are continued during working hours, and cases of sudden illness at work are referred to them also.

A Human View of a Great Port

M. W. GOLDBLATT

It is characteristically Italian that even so apparently a workaday subject as the industrial medical problem of work in docks, including its physiopathological, clinical, and preventive aspects should be presented in this book* with covers showing a detail of Bordone's seventeenth-century picture of the port of Genoa in colour. This beautiful picture, which resembles a kind of aerial abstract of the conception one has of old Genoa, inevitably tells us that, even in those far-off days, a great port involved almost every working activity which man must undertake. The congestion of dwellings, storehouses, building and repair shops, administration and commercial buildings, guildhalls, loading and unloading quays, breakwaters, ships big and small, coming and going, landing stages, all combine to present to us a world, at once beautiful, vital, questing and, in every sense, bigger than man, its creator, himself. In this picture by Bordone we realize the time when the quest had to be undertaken in the hard way. If, today the way is different, mechanized, quick, massive, it nevertheless remains hard. In almost every field of activity embraced in the term dock work the call upon qualities of strength, judgment, expertise, courage, skilful cooperation, and responsibility is more insistent today than it was in those early days.

Dock work entails a peculiarly strong sense of responsibility. The loader in the hold knows he endangers the sailor if careless; the pump operator knows the life of the underwater man depends on him; the crane operator can maim a stacker ; the port doctor knows he endangers the population if he is too facile in lowering the Yellow Jack; the industrial doctor knows he must be rigid in his standards of acceptance for work, more so indeed, than in most other industries; the loader on shore knows that careless handling of drums, kegs, and other containers may subject his opposite number at a port of call in dangers, toxic or dermatitic; the welder in dry dock knows that on the effectiveness of his weld depend the lives and property of many people. Like miners, dock workers have something different about them. In modern times some degree of travel has come within the means of most people in Britain, but even in Britain the dock worker gets to know more about foreign lands and peoples than do the generality of workers. In the great ports of Europe every tongue and every kind of face and dress are daily heard and seen, so that the dock worker inevitably acquires a cosmopolitan outlook and gets to know what happens in his field of work or interest abroad. There is a sense of importance and immediacy in the efforts of a dock worker which is different from that

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* **Il Lavoro Portuale (Dock Work).** By Francesco Molfino and Damiano Zannini. (Pp. 319+index; illustrated.) Milano: Edizione I.N.A.I.L. 1956.

experienced by other categories of workers. He experiences the satisfaction of completion, so much denied to other workers in this world of mass production, and does not ever become an automaton. The irregularities of his trade or craft are inherent in the nature of affairs at a port and like the mariner he has learnt to wait, especially nowadays when waiting and being called have become a much more comfortable and organized proceeding. He has, on the whole, an open-air life and as the years advance does not lose all the romance which, in his rough, perhaps coarse way, he has felt in his earlier days.

But, of course, considerable numbers of port workers pass the working day inside ships, where, in hot countries or seasons, the low specific heat of the metallic hull soon induces extremely uncomfortable temperatures. Moreover, as is emphasized by Molfino and Zannini a great deal of work on ships in port is carried out in confined, cramped spaces so that any advantages of sea breezes are entirely lost, especially when other operations are going on which require services such as steam power, heat, furnaces, and so on. Such jobs as descaling boilers, repair of pumps while boilers are going and others mentioned by the present authors all involve extremely trying conditions of temperature and humidity. They quote the observations of Bottner, which they have confirmed, in which two hours at 40° C. with 50% relative humidity led to losses of weight of ½ to 2 kg. and of 1·2 to 11 g. NaCl in the perspiration. The manner in which workmen in time acquire resistance to such conditions is something of a puzzle and the known inborn tolerance of negro workers is variously attributed to better peripheral circulation, better development of sweat glands, and the secretion of more volatile sweat.

That accidents in docks should be frequent is inevitable. The crude figures for men in Britain were 32 fatal and 6,473 non-fatal in 1954, 48 fatal and 7,188 non-fatal in 1955. The authors give figures from official sources; these may be tabulated thus:

ACCIDENTS IN THE PORT OF GENOA
PER 1,000 MAN-YEARS

	Docks			Industry in General	Transport and Storage	Lost Time in Dock Accidents	
	Full-time Workers	Casual Workers	Fatal			11-20 Days	6-10 Days
1952	125(359)*	263(371)	1	121·4	107·7	40%	26%
1953	157(446)	379(428)	1	—	—	—	—

*Total accidents in brackets.

From our memory of the activities in Genoa, these figures seem not unsatisfactory, and indeed Molfino, while not complacent, feels that there has been an immense improvement attributable, in part, to the 1932 Convention (given *in extenso* in the text) and the regulations of the Port of Genoa (also appended in full) for the prevention of accidents. From that aspect which most impressed Ramazzini, the effects of lifting and carrying heavy loads (Cap 35, " De mortis artificum diatriba " not Cap 34 as given by the authors) with resulting fatigue, strain and ultimately pulmonary, muscular, joint, and vertebral troubles, the present-day dock worker is, on the whole, liberated; for muscular effort there are substituted use of small muscles in movements which demand judgment, agility, precision rather than strength, combined with sensitivity, quick perception and reaction following rapidly selective volition rather than labour; cerebration rather than muscular effort. Nevertheless, the authors point out, strain and fatigue appear even today in workers who are insufficiently trained or have lost confidence. Neurasthenic symptoms can readily arise in crane workers as a result of the maintained strain of responsibility for work in which inaccuracy or even slight fatigue can result in disaster.

In a discussion of the pneumoconiosis of coal unloaders, the authors give their analysis of 341 cases from the insurance records of workers in the port of Genoa who had been examined clinically and radiologically. While recognizing that this is a very small sample, the authors draw attention to the high incidence of suspected active pulmonary tuberculosis (3·8%) and appear to incline somewhat to the view of Castellino that anthracosis and tuberculosis may be associated as an occupational hazard, especially after 20 or more years in this work. It might have been more rewarding if the authors had waited for more data.

There are in this well-produced volume, simple, clear discussions of the problems of the diver and caisson worker and detailed data of decompression times, consideration of the hazards of welding (conclusions here are perhaps less optimistic than those reached in Britain), descriptions of many operations in the docks with many photographs which in some measure bring the dock worker's life to our minds. Guidance on preventive measures occupies nearly one-quarter of the volume and especially interesting are those on selection of workers for special kinds of work.

The book is well documented and very easy to read. Indeed, if a foreigner may presume to say so, scientific or medical Italian is singularly uninspiring and does not evoke the pleasure which is traditionally associated with this beautiful language.

The British Occupational Hygiene Society

An ordinary scientific meeting of the Society was held at the London School of Hygiene and Tropical Medicine on November 16, 1957. The chair was taken by the President, Dr. P. Pringle, and some 50 members were present. Four short communications were presented and summaries of these are given below.

Lighting in Industry

J. F. ROPER

From the Lighting Service Bureau

Lighting installations are generally planned to give certain illumination values in accordance with the recommendations of the Illuminating Engineering Society, which are based on the visual difficulty of the work being done, and take into account the practicability and cost of the lighting in relation to other costs. For this reason values of illumination recommended vary from country to country and generally according to the degree of industrialization.

The lighting installation may be planned to give a reasonably uniform illumination over the whole working area or may be localized in relation to the layout of benches and machines. Supplementary local lighting should only be used where the other systems are inadequate.

Shadows.—Lighting, having a strong directional component, can cause annoying or dangerous shadows but some shadow is necessary to appreciate form. Daylight from side windows should be supplemented by artificial lighting over the inner parts of the room to counteract shadows and increase the illumination over those parts.

Glare.—No installation which is glaring can be either comfortable or fully effective. To prevent glare, not only should all lamps and very bright parts of fittings be screened from normal view, but also the whole interior should be treated in such a way as to avoid excessive contrasts of light and dark. The majority of complaints about fluorescent lighting are due to the lamps being used unscreened to save a little expense.

The contribution which good lighting makes to the amenity or welfare aspect of the interior is probably, in the long run, at least as important as its influence in increasing production by providing better seeing conditions.

Manual Handling Operations in Modern Industry

R. J. WHITNEY

From the M.R.C. Unit for Research on Working Efficiency

This paper covered the following subjects: The nature and extent of handling operations in modern industry; the need for an improvement in handling efficiency and a reduction of handling accidents; available information on the performance of handling operations in relation to the type of information required; current investigations on the strength of the lifting operation in man.

Experiments in Foundry Ventilation

W. D. BAMFORD

From the British Cast Iron Research Association and Central Electricity Authority

The fundamental factors involved in the formation, raising, and dispersal of dust and fumes in thermal currents, cross draughts, and wheel air currents have been investigated. The results of these investigations, together with additional data from original work on exhaust air velocities, have provided a basis of knowledge which enables the methods of suppression or control of dust and fumes by air movement and other means to be worked out. The design data were established from laboratory and field tests in foundries and have been found to provide a sound basis for the economical solution of most practical problems relating to control at the source of dust in foundries. These data can be applied with equal effectiveness in many other industries where dust is dispersed by cross draughts alone or with thermal currents. This paper described the nature and extent of the problems that had to be solved in order to obtain the fundamental data required for the design of ventilating systems in foundries and also indicated how this information could be given practical application.

Special Problems of the Fine Chemical and Pharmaceutical Industries

T. DEWING

From Burroughs Wellcome & Co.

This paper dealt with the special problems imposed by the need to use many small manufacturing processes, often involving widely different occupational hazards, at any one time. Among the hazards considered were toxic risks, fire risks, and the problems associated with the handling of products.

Public Lecture

After the meeting there was a public lecture by Professor T. F. Hatch entitled " Human Engineering ". (Professor Hatch holds the chair of Industrial Health Engineering at the University of Pittsburgh.)

BOOK REVIEWS

Uses of Epidemiology. By J. N. Morris. (Pp.viii+135; illustrated. 19*s.* 6*d.*) Edinburgh and London: E. & S. Livingstone. 1957.

One of the many odd things about social medicine is that it has three legs to stand on. In this it has been fortunate indeed for the tripod of public health, medical sociology, and epidemiology has withstood some recent serious attempts to dislodge it from the medical curriculum, and even from medicine itself. The subject has so far been least successful in holding its own in London, but now it may be making a come-back. Dr. Morris's book is the second of a string of books on social medicine promised for this year from London medical schools and research units. The first* was reviewed here recently.

Though he is obviously well qualified to discuss all three legs of his subject, Dr. Morris's main interest is epidemiology. In this book he sets out to describe the rapid broadening of the subject which has taken place recently by showing some of the ways in which the method has been used.

The new epidemiology is very broad indeed. " If it moves, salute, and if it doesn't, paint it white ", is perhaps a good enough classification for those entering the Army ! " If it's one patient, it's clinical, and if it's more than one it's epidemiological " seems to be the new and equally rough classification in medicine. In fact, the term may be in danger of losing rather than gaining from the very wide interpretations of today. However, some broadening was obviously necessary, if only because epidemiologists do such queer things these days, and the older interpretations left important gaps which had to be filled.

When it is examined closely, both inside Dr. Morris's book and in the world outside, it is seen that what epidemiology really does in observing community disease patterns is to define in various ways vulnerable groups of people. These detailed descriptions of the characteristics of sick people in time or space, by age, sex, or by some social yardstick—such as our own crude yet invaluable " social class " (or even such esoteric classifications as " culture pattern "), can be used in many ways. First, and most important, of course, it is used in the search for the " causes " of disease. Half of this book is rightly devoted to showing how the characteristics of vulnerable groups can be used to provide links in the causal chain—" hunches ", as the author would say—as to how the thing works. Dr. Morris is rightly reserved in his use of the word " cause " for there can be few diseases left in which the clear pattern of cause and effect is found today as it was by our predecessors of the nineteenth century. The " new " diseases have a multitude of interacting causes and some of the difficulty in unravelling them comes from the poor definition of syndromes by clinicians. Another use, then, of epidemiology is to help to define more clearly syndromes in current use. With the clarification of syndromes and the breaking down of large disease groups such as peptic ulcer and atherosclerosis into their constituent and differently behaving entities more is learned not only of causes, but also of the " community need " for medical care. Information about the functioning of health services and how well these " community needs " are met is a first step towards the assessment of the quality of medical care, " evaluation " as the Americans call it, and epidemiology can help us here. For example, the discovery of different mortality rates in similar age/sex groups for the same disease in different types of hospital immediately raises the question of the quality of care in the two places. The epidemiologist, having been caught like this before, re-examines his populations while speculating about the quality and number of staff in the hospitals.

The increasing importance for health of personal behaviour, particularly in the new industries, in leisure activity, and in diet, is emphasized by the striking differences in individual chances or expectations of encountering disease. Epidemiology with its new ways of looking at the cohort, the life table, and the fashionable " prospective " study can help to define these critical features of our lives.

This is a fascinating and, at the same time, an irritating book. It is just what we have all wanted, but it is far too short to do justice to the subject (rather over 55 pages of large type, excluding tables, appendices, etc.). A few of the figures and some unimportant details of text and presentation could well be improved. But this is real social medicine and shortcomings of production are of small import beside the author's enthusiasm and flow of ideas. Obviously the new epidemiology reflects the new medicine, and it is very exciting.

E. MAURICE BACKETT

Pneumoconiosis: Industrial Diseases of the Lung Caused by Dust. By P. F. Holt. (Pp. 268; illustrated. 50*s.*) London: Edward Arnold. 1957.

Pneumoconiosis, of which the most familiar varieties are pneumoconiosis of coalworkers, silicosis, and asbestosis, is the most serious occupational disease. It affects a wide range of workers—male and female—in mines and factories throughout the world. While many of the hazards have been recognized for nearly two centuries, new ones continue to arise from new processes and new

* **Principles of Epidemiology.** Taylor and Knowelden, Churchill, 1957.

materials. To scientists in many fields such as biology, chemistry, and physics, the disease presents many fundamental problems for research. Thus the physician is concerned with the many complex problems of diagnosis, measurement of respiratory function, and the treatment, management, and rehabilitation of patients. Others are interested in the epidemiology of the disease and its social consequences. Prevention of the disease offers a constant challenge to the ingenuity and tenacity of engineers and others. For governments the problem is preventive legislation and schemes of compensation. Investigations in these several fields produce a seemingly unending spate of literature from almost every country in the world. It is quite impossible for any single individual—language difficulties apart—to keep abreast of the growing knowledge in all branches of pneumoconiosis research. Moreover, the various fields of enquiry have become so narrow and specialized and many of the technical researches so recondite that the general reader is unable to follow them.

All are increasingly dependent on abstracts and commentaries by experts for current information. These are admirably exemplified by the *Bulletin of Hygiene*.

In the present volume Dr. Holt, distinguished over many years for his chemical and physical researches on silica and fibrogenesis, has undertaken to present background material on the subject, which, he hopes, will inform and assist medical specialists, physicists, chemists, engineers, administrators, and others. In the preface he states " that the intention of this book is to provide sufficient material to act as an introduction and to indicate where further information can be found." This demands an encyclopaedic knowledge of the subject. Moreover, it requires great objectivity and self discipline if the author is to achieve a balanced and proper selection of the enormous literature. Almost inevitably the author will prove more expert in his selection and appraisement in his own special field than in others. Likewise, the reviewer cannot avoid the same weakness for he will judge the work by the adequacy of the section, which deals with his special interest. The predicament is not new or peculiar to this subject. It has led to team authorship under the direction of an editor.

Dr. Holt's book consists of 236 pages comprising 18 chapters. The first chapter is a historical survey supplemented by statistics of mortality from various sources. In view of the purpose of the book to direct the reader to sources of further information it is disconcerting to find on the very first page that Arlidge is cited as Aldridge and as this error is repeated in the bibliography and in the author index the printer can be exculpated. Only a little farther on it is stated that " Josiah Wedgwood introduced finely powdered calcined flint into his white pottery in 1720 ". This, if one might say so, is a preconception for the great potter was not born until 1730. Generally the innovation is attributed to John Astbury, a North Staffordshire earthenware manufacturer. Chapters 2 and 3 deal with the structure and properties of some industrial minerals and the chemistry of the surfaces of minerals. In the succeeding six chapters discussion is narrowed to silicic acid and its derivatives and their fibrogenic action in the lung. This is Dr. Holt's special field and much of the material, I fear, is beyond the comprehension of all but a few, of which I am not one, industrial medical officers. Thereafter successive chapters deal with silicosis, asbestosis and coal-miners' (not coalworkers') pneumoconiosis. The effects of other siliceous and non-siliceous dusts are then discussed. Beryllium receives relatively considerable notice. I do not dispute that beryllium dust causes lesions—often extensive—in the lungs but I doubt if berylliosis is rightly included among the pneumoconioses. Within its necessarily restricted limits the chapter on protective measures against pneumoconiosis in mines, factories, and workshops gives a good account of modern practice and matches up to the author's purpose. The chapter on the measurement of dust concentrations is based on a series of papers written by the author and published in *Metallurgia* in 1951. The final chapter is devoted to a summary of compensation legislation and factory regulations. In no subject is the need to be accurate and precise more important than in the law. The opening sentence that " in Great Britain compensation for *pneumoconiosis* (italics mine) was first provided . . . in 1919 " is inaccurate; the legislation then applied narrowly to silicosis. The distinction is important and emphasizes the laxity in the use of terms which all too commonly exists in the literature of the subject.

An excellent bibliography, enhanced by author and subject indexes, comprises 657 references. Some researcher may, on occasion, be irritated by the errors in such references as Aldridge (3), Permeggioni (548), Commins (611), Scheppers (630), and Gwyrpai (490). The book contains a wealth of scientific material but pneumoconiosis is basically a disease affecting the lives of thousands of workmen and their dependants. For this reason I think—particularly for the benefit of non-medical readers—that a short introductory chapter on the medical aspects might, with advantage, have been included.

Despite the criticisms which I have made, this book is a *tour de force* and a testimony to the wide range of Dr. Holt's knowledge. The paper and printing are excellent and the illustrations well produced. I can offer no higher commendation than to say that I am glad to have this volume in my library and that it will be a constant source of reference.

A. MEIKLEJOHN

Chronic Bronchitis in Newcastle-upon-Tyne. By A. G. Ogilvie and D. J. Newell. (Pp. vii + 115; 6 figures. 15*s*.) Edinburgh and London: E. & S. Livingstone. 1957.

This book describes a survey designed to discover the prevalence rate of chronic bronchitis in Newcastle-upon-Tyne. In addition an attempt was made to find out more about the aetiology of bronchitis by comparing the present and past living conditions and the family histories of a group of bronchitics with a group of controls. The task undertaken by Ogilvie and Newell, to survey a whole city of 281,000 inhabitants, was one that might well have discouraged Hercules. One in 40 of all the houses in the city were visited by 43 health visitors who, on the basis of an agreed definition, placed all the men

and women over the age of 30 into one of two categories " presumptive bronchitics " and " presumptive non-bronchitics". The definition of chronic bronchitis adopted was " a long-standing condition, the essential features of which are a cough with sputum, persistent through the winter or throughout the year, in the absence of other causative respiratory disease. A minimum duration of two years is essential for its recognition."

The determination with which the survey was prosecuted and the success it achieved can be judged from the fact that only 26 out of 3,866 people interviewed refused all information and 1,202 out of 1,250 required for examination at hospital were in the end examined.

All of the " presumptive bronchitics " were examined clinically at hospital and had their chests radiographed and an approximately equal matched group of " presumptive non-bronchitics " was selected by a random procedure and also examined at hospital. The three doctors carrying out the clinical examination quite often did not agree with the health visitors' assessment. Out of 340 selected as bronchitics by the health visitors, the doctors selected 272, and out of 320 selected as non-bronchitic by the health visitors, the doctor diagnosed 81 as having bronchitis. This demonstrates the great difficulty there is in diagnosing on the basis of a questionnaire the early stages of bronchitis. The final prevalence rate given for men of all ages over 30 was 36% and for women it was 17%.

When their bronchitic and non-bronchitic groups had been established and matched for age and sex the authors proceeded to examine the environmental histories in the two groups. They found that the bronchitics had had an excess of early and acute respiratory illnesses and had experienced chest illnesses more frequently than the control subjects. A much higher proportion of the bronchitics complained of dyspnoea. Only 11% of the male bronchitics were non-smokers compared with 26% of the controls. The disease was commoner in the eastern and western industrial areas of the city than in the northern districts. It was associated with a higher density of population and there was a smaller proportion of the two upper social classes in the bronchitic group. No specific occupation was found to suffer a high rate though the clerical, professional, and administrative groups had a low incidence. There was some association with extremes of temperature and with draughts and dusts encountered at work and a strong relationship was found between the incidence of the disease and the number of years of unemployment which had been experienced by the subjects. This and the fact that there was a similar social class gradient in the wives as that found in the men suggested that economic rather than specific occupational conditions were of aetiological importance.

An interesting finding was that 62% of the bronchitics considered that the disease was neither progressing nor getting better. Out of 1,071 whose chests were radiographed, one was found to have a bronchial carcinoma.

The authors found a high incidence of asthma in the bronchitics but this can perhaps be explained by the fact that " bronchial stridor ", presumably equivalent to wheezing or sibilant rhonchi, was taken to indicate asthma, whereas many observers would regard this physical sign as a normal accompaniment of chronic bronchitis in the middle-aged and elderly. It is argued that this indicates hypersensitiveness and that therefore the hypersensitive individual is especially liable to chronic bronchitis. In addition to the detailed report of the survey there are two chapters on the epidemiology and the pathology and bacteriology of chronic bronchitis.

This book is indispensable to those who are interested in the study of chronic bronchitis by epidemiological methods, as it describes on a larger scale than hitherto attempted one way in which a prevalence study of a whole community can be attempted, the difficulties that can be expected, and the valuable results that can be achieved.

J. PEMBERTON

Charles Turner Thackrah: The Effects of Arts, Trades and Professions on Health and Longevity. With an Introductory Essay on his Life, Work, and Times. By A. Meiklejohn. (Pp. 238+50; illustrated. 25*s*.) Edinburgh and London: E. & S. Livingstone. 1957.

Charles Turner Thackrah is commonly spoken of as the Father of British Occupational Medicine, and with reason since in his book he propounded for the first time the conception of industrial health based on prevention. In this sense indeed Thackrah's influence has extended far beyond the shores of Britain for physicians in industry everywhere all over the world are today his disciples and inheritors.

His book was first published in 1831 and it was highly spoken of by all the reviewers in the journals of the day. The *Lancet* confidently recommended the work to the profession and trusted that Thackrah would find some successful followers " in the benevolent cause he thus invites others to pursue ". As Dr. Meiklejohn says, " Those who study the work now for the first time will make their own assessment. Much will depend . . . on what they bring to it for author and reader are complementary ".

The first edition was soon sold out and although the second appeared a year later, both are hard to come by, and Dr. Meiklejohn, his publishers, and the Wellcome Trust (without whose generous help publication would not have been possible) have put all those engaged in the practice of occupational health, and indeed the whole profession, in their debt by making this medical classic accessible to everyone almost in its original form, for the present volume is not merely a reprint—it is a facsimile which has been reproduced by photolithography.

In addition, Dr. Meiklejohn has contributed a biographical essay which is the first full and truly authoritative account of Thackrah which has appeared. Several essays have in fact previously been written about him but all have been based on the memoir by Dr. Henry Yates Whytehead in 1834 to the posthumous second edition of Thackrah's work on the nature and properties of blood. Whytehead knew Thackrah well since he had served his apprenticeship with him, and he was one of the executors of his will and was also specifically named in it as the legatee of all his former master's manuscripts. So Whytehead can be regarded as a reliable original

source. Dr. Meiklejohn has of course drawn on the material in this first-hand account, but he has also himself carried out extensive researches which have thrown much new light on Thackrah. He has sought out the three original portraits of Thackrah which have survived and all are reproduced as illustrations in the present volume. The erudition shown in this essay is immense. This is in fact a considerable piece of historical research: the prose in which it is written is elegant and simple, and the whole forms a work of art which is deserving of the highest praise.

Some of Dr. Meiklejohn's more intimate friends, especially perhaps his fellow members of the Thackrah Club, know the difficulties which have had to be overcome in order to make publication of this book possible, but he has been indefatigable and has in the end surmounted every obstacle with the happy result which is now seen. Dr. Meiklejohn is to be warmly congratulated on a great achievement.

GERALD KEATINGE

Youth at Work. By M. E. M. Herford. (Pp. 154 + Appendix. 18*s.* 6*d.*) London: Max Parrish. 1957.

It was sometimes complained, in the early days, that the work of the certifying factory surgeon, as he was then called, was no better than it ought to be. Perhaps his main function at that time was to act as a check on the employment of young people in contravention of the age limits imposed by statute; it would in any case have been unrealistic to expect him to be very highly selective in his decisions on fitness for employment in view of the high prevalence of severe physical defect among young people. Now the climate has greatly changed, and, with the development of school health services, it has come to be expected as reasonable that the successors of the certifying factory surgeons should make a more positive contribution to the employment of young persons and that their work should be more closely related to that of the school medical service.

Working on this basis, Dr. Herford, in the capacity of an appointed factory doctor, has presented, in "Youth at Work", a study of adolescents in industry in the Slough area, which has a total population of about 140,000; it is essentially an area of light industry. Dr. Herford describes the health problems encountered and the main defects found. Not many of the young people with a disability qualifying for admission to the Disabled Persons Register were doing, or trying to do, a job that was too heavy for them at that stage; but facilities for training were inadequate. A number of the mentally handicapped young persons who had been notified under the Education Act as being in need of supervision after leaving school were doing simple routine jobs with success—sometimes better than their supposedly more intelligent companions. In general, the position of apprentices and apprenticeship did not appear to be very satisfactory and this helped to bring the system into disrepute, though for apprenticeship to some crafts, such as electrical engineering and cabinet-making, there were insufficient vacancies. The disturbing effect of imminent National Service on the young worker was found to be decreasing; Dr. Herford believes that few, if any, of the boys who might be expected to take apprenticeships were deterred from doing so by the thought of National Service, though the desire to get Service over, or to go in company with mates, was sometimes a convenient excuse for breaking an apprenticeship. Nearly 20% of the young persons studied came from homes broken by illness, separation, or death; and these youngsters had more difficulty than the others in settling down at work.

Dr. Herford concludes that the duties of the appointed factory doctor should be on an essentially whole-time basis; that he should be primarily a member of the staff of the Medical Inspectorate of Factories, but should hold a joint appointment with the local authority as an assistant school medical officer; that all young persons should be examined regardless of occupation; that the appointed factory doctor should be appointed medical adviser to the Youth Employment Service and should be provided with a secretary seconded from the staff of that Service; that school medical records should be submitted automatically to the appointed factory doctor when the children leave school; and that it would be an advantage to have the appointed factory doctor associated with a university department.

T. FERGUSON

The Social Problem of Mental Deficiency. By N. O'Connor and J. Tizard. (Pp. 190. 30*s.*) London and New York: Pergamon Press. 1956.

Mental deficiency is indeed a grave social problem, but there are still far too few people who realize this, and fewer who act on it. Industry, and industrial medical and personnel officers in particular, have a great opportunity to educate the public in this respect, and in this will be greatly helped by these two authors. The book contains a survey of the background and also their own original research, reported or referred to in its chapters. These include studies in predicting occupational success, in training skills, and in adaptation to community life.

The scientific value of these studies is not in doubt but the accounts are written in a somewhat pedestrian style, and are not very readable. This is a pity for it may blind many readers to the real value of the work and of this book.

What really matters is that there is here a challenge to established ideas of mental deficiency, ideas moreover on which much of present-day building, staffing, and occupation (or the lack of it) is based. Here is strong evidence to show that with suitable training, many high-grade defectives can be taught to earn their living and to do so in a way which is of real value to the community, and be far happier thereby. This is of course based on the pioneer work of such people as Laing of Darenth Park in this field: but the authors take the work a stage further in their assessment of predictability and of the type of training required. Further, they describe and summarize similar work on the successful employment of imbeciles in experimental workshops. All this must give food for thought to the superintendents of colonies, and those who plan, and pay for, and select their medical and nursing staff: for few are well enough equipped to

carry out the patient and skilled teaching clearly required. Surely it will be necessary to look on colonies in future as predominantly educative, and only custodial for the exceptional case. This concept no doubt has led some to suggest that defectives should become the responsibility of the Ministry of Education. It would naturally have to be clear, first, that the latter would welcome such a charge with enthusiasm and forethought and not regard it as a burden.

With all this, it seems fair to hope that there will be a gradual change to far fuller employment of defectives, inside colonies and out. For the latter, of course, there will be difficulties: many firms, for instance, will be reluctant to cooperate. Perhaps here, too, little credit has been given to the good will, broadmindedness, and enlightened supervision of the Kolster-Brandes staff (page 99) which was of an order seldom likely to be matched. Further, signs of unemployment could throw grave and sudden stress on employed defectives. The handling of these matters will be, in fact, further social problems. Therefore, the more the public knows, and accepts its own responsibility, the better. The divorce between local health authorities (who can be public educators) and colonies for mental defectives is a pity, here. The gap can be bridged by the regional hospital board officers, and by voluntary bodies, such as national associations, or locally, friends of hospitals. In this way prejudice may slowly be overcome, and the real potential of the defectives appreciated. This would thus constitute an appeal to the public not only to fill the grave deficiencies in the mental deficiency nursing service, but to do so with people inspired not simply to care, but also to teach.

R. F. TREDGOLD

Air Pollution Handbook. Edited by Paul L. Magill, Francis R. Holden, and Charles Ackley; Editorial Consultant: Frederick G. Sawyer. (Pp. xi + 14 sections; illustrated. £5 12*s.* 6*d.*) London: McGraw-Hill. 1956.

The relatively new and expanding subject of air pollution crosses the boundaries of most scientific disciplines and is steadily accumulating a literature of its own. This latest addition will form an invaluable reference work to the specialist and cannot be too strongly recommended to scientific workers entering the field for the first time. There are 14 self-contained sections, each of which deals with the present state of knowledge in a particular field. Many of the contributors are well known to research workers in this country as well as in the United States, and the book is edited by staff of the Stanford Research Institute in California, where a large amount of research on air pollution has been undertaken. The scope is wide and the general layout good. Sections on sources and city planning are followed by others on the behaviour of pollutants in the atmosphere and on weather effects. Then follow three sections on the effects of air pollution on human beings, animals, and plants. Sampling, analytical and experimental test methods are next discussed, followed by a long section on abatement and one on legal aspects. Most of the material presented will be of international value, although some of the practical problems discussed are less applicable to this country. The emphasis tends to lie on pollution from specific industrial sources, for there is much less domestic pollution in the United States than in this country. Each section contains a useful bibliography, and after allowing for some duplication, there are well over 1,000 references, extending up to 1954.

Those who are seeking a general account of the community air pollution problem should read Section 2 first. This is concerned mainly with problems of city planning and industrial plant location, but its scope is much wider and it provides an excellent introduction to the other more technical sections. The one on sources and their control deals at length with the properties of fuels and the ways in which they are used. It shows the important part now played by natural gas and fuel oil in meeting the energy requirements of the United States, and compares the position with that in Great Britain. Means of controlling all major emissions are reviewed, but the question of flue-gas scrubbing is dealt with very briefly. The sections on physics of the atmosphere, the evaluation of weather effects and visibility and air pollution contain an immense amount of material of fundamental importance. The treatment is, however, highly mathematical and they should be left to the specialist in each field.

Dr. Phair's chapter on the epidemiology of air pollution is disappointing. It occupies only 14 pages compared with an average of 49 in the other sections, and deals at such length with the general philosophical problem that it lacks any detail of value. This may be inevitable, for the literature on this aspect is quite limited. However, it seems a pity to dismiss all past attempts at demonstrating an effect of ordinary air pollution as not being fruitful. There is a short but useful section on the effects of air pollutants on farm animals. It deals mainly with the specific problems of arsenic, fluorine, and lead poisoning, and provides an extensive bibliography. Air pollution has widespread effects on vegetation and the section on plants provides a valuable summary of these. Several pages are devoted to smog damage, and the authors are careful to draw the distinction between Los Angeles smog and the mixtures of smoke and fog which occur elsewhere.

The section on sampling procedures seems to cover most of the problems likely to be encountered by the air pollution investigator, from samples of stack gases to colour transparencies of cow's teeth. Proper emphasis is given to the various pitfalls in sampling and the sentence " All too frequently, samples are collected that, regardless of the analytical techniques applied, will not provide the information that is necessary " could well be underlined. Frequent references are made to specialized equipment available in the United States, and in most cases British readers should be able to find something similar here.

At times one feels that the editors have gone a little too far in splitting the book up into so many sections. Dr. Cholak himself, in his section on analytical methods, points out that there is inevitably some overlap with the preceding one on sampling procedures. It might have been more economical to have combined these. A fairly complete catalogue of analytical methods is provided, but the reader is left to consult original papers for details.

There is an admirable section on experimental test methods by Dr. Silverman in which he describes the design and operation of exposure chambers and methods of producing various aerosols. The numerous practical details and diagrams included will be of immediate interest to those wishing to expose human subjects or animals to suspect pollutants, and to others who need to prepare artificially polluted atmospheres for testing filters or sampling methods.

By far the longest section is on equipment and processes for abating air pollution. There are 10 authors, headed by Dr. H. F. Johnstone, of Urbana, who is the leading authority on industrial emissions, particularly of sulphuric acid. This excellent survey covers questions such as the effect of stack height on the dispersal of pollutants, the collection of aerosols by impaction, filtration, scrubbing, electrostatic and sonic precipitation, and the control of gaseous pollutants. There is again a certain amount of overlap with earlier sections, but the seven pages on the removal of sulphur dioxide are largely complementary to those on the same subject in the first section.

The book concludes with a section on legislation in which the author sets out to " (1) review some of the basic legal considerations involved, (2) point out some of the issues with which pollution legislation will need to deal, and (3) report what has been done and is proposed by way of air pollution legislation." It provides a useful summary of American ordinances, most of which relate to single cities or counties. The author refers to the difficulty of defining air pollution and restricts his discussion to " the presence in the atmosphere of substances, resulting from acts of man, in quantities which are or may become injurious to human, plant or animal life or to property; all aspects of employer-employee relationship as to health and safety hazards are excluded." This might well be accepted as defining the limits of " community air pollution ".

R. E. WALLER

Books Received

(Review in a later issue is not precluded by notice here of books recently received.)

Gastric and Duodenal Ulcer (Report and Recommendations). (Pp. 6. 1*s.* 6*d.*) Pamphlet issued by the British Council for Rehabilitation, London. 1957.

The Chemical Industry Facts Book, 3rd ed. (Pp. 149; illustrated. $1.75.) Issued by the Manufacturing Chemists' Association, Washington, D.C. 1957.

Lavorazioni che espongono all'azione del Piombo-Tetraetile. By Raffaele Guiliano and Mario Rafanelli. (Pp. 64; 11 figures. Price not stated.) Rome: Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro. 1957.

Public Health and Social Services, 4th ed. By D. H. Geffen, L. Farrar-Brown, and M. D. Warren. (Pp. 160. 9*s.*) London: Edward Arnold. 1957.

Practical Psychiatry for Industrial Physicians. By W. Donald Ross. (Pp. xx + 401. 57*s.* 6*d.*) Oxford: Blackwell Scientific Publications; Springfield (Illinois): Charles C. Thomas. 1956.

Size and Morale, Part II: A Further Study of Attendance at Work in Large and Small Units. (Pp. 36. 3*s.*) London: The Acton Society Trust. 1957.

Microdiffusion Analysis and Volumetric Error, 4th revised ed. By Edward J. Conway. (Pp. xviii + 465; 79 figures. 42*s.*) London: Crosby Lockwood. 1957.

First Aid and Early Treatment of Burns in the Royal Air Force, 2nd ed. [A.M. Pamphlet 168]. (Pp. 70; 14 figures. 3*s.*) London: Air Ministry. 1956.

The Practice of Industrial Medicine, 2nd ed. By T. A. Lloyd-Davies, with a chapter on *The Hazards of Coal Mining* by J. M. Rogan. (Pp. vii + 282; 15 figures. 30*s.*) London: J. & A. Churchill. 1957.

Medical Writing, the Technic and the Art, 3rd ed. (Pp. x + 262; 36 figures. 52*s.* 6*d.*; $7.00.) London, New York, Toronto: McGraw-Hill. 1957.

The Nuffield Foundation: Twelfth Report for the year ended March 31, 1957. (Pp. 168.) London: Nuffield Foundation. 1957.

Taschenbach der Arbeitsmedizin. By H. Buckup, (Pp. 272; 19 figures. DM 27.-.) Stuttgart: Georg Thieme. 1957.

Cronica y Actas del III congresso nacional de medicina y Seguridad del Trabajo, Madrid, 1957. (Pp. 451; illustrated.) Madrid: Editorial Nuevas Graficas. 1957.

Malatti causate da Cromo e Composti. By Guiseppi Rombolà. (Pp. 59; monograph. L. 350.-.) Rome: Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro. 1957.

Digest of Statistics Analysing Certificates of Incapacity 1954/55. (76 tables, 2 charts; multigraphed.) London: Ministry of Pensions and National Insurance. 1957.

L'Hygiène et la Securité dans l'emploi des acides forts. I: L'Acide Sulfurique et ses Dangers. By A. Vallaud and P. Salmon; Foreword by Henri Desoille. (Pp. 180; 71 figures, 1 colour plate. Fr. frs. 300.-.) Paris: Institut National de Securité.

Industrial Toxicology, 2nd ed. By Laurence T. Fairhall. (Pp. xii + 376. 80*s.*) London: Baillière, Tindall & Cox. 1957.

A Short History of Public Health. By C. Fraser Brockington. (Pp. vii + 235. 15*s.*) London: J. & A. Churchill. 1956.

Juvenile Epilepsy. Report of a Study Group. *Wld. Hlth tech. Organ. Rep. Ser. No.* 130. (Pp. 44. 1*s.* 9*d.*) London: H.M. Stationery Office; Geneva: World Health Organization. 1957.

Third International Congress of Photofluorography

The third international congress of photofluorography will take place in Stockholm from Wednesday, August 20, to Saturday, August 23, 1958.

There will be discussions on the general and special problems of photofluorography and its importance in the control of pulmonary tuberculosis as well as of other thoracic diseases.

All information can be obtained from the Congress office, Stockholm, 5, Post-box 5097.

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Boxes of 100	15/9 each
L.625 (IW)	2 1/4" × 1"
Boxes of 50	8/– each
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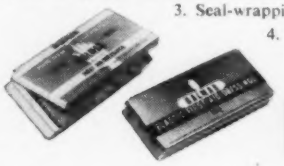

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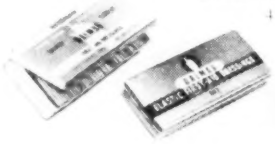

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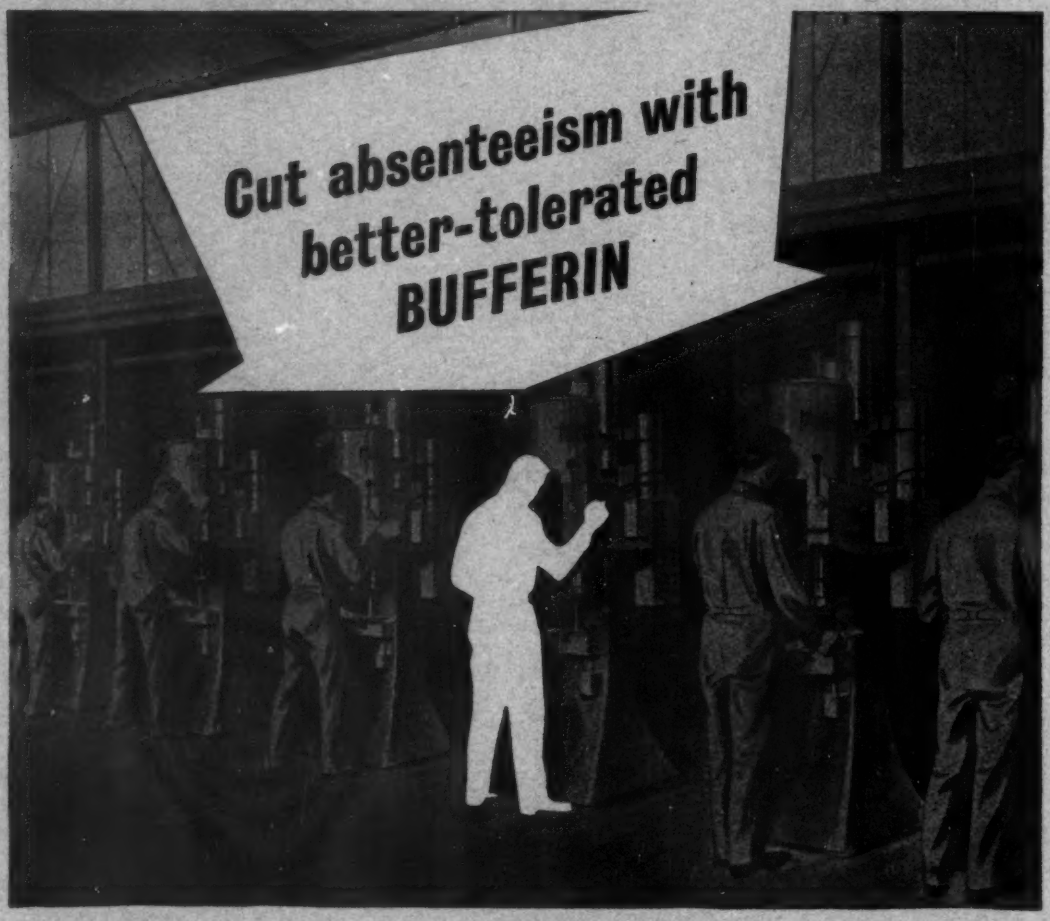

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